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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

COLLOQUIUM ON SATELLITE BROADCASTING

OCTOBER 8, 1965

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DIGEST

of the

PROCEEDINGS OF THE COLLOQUIUM

on

SATELLITE BROADCASTING

October 8, 1965

Washington, D. C.

SPONSORED BY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
DIRECTORATE

of

COMMUNICATION AND NAVIGATION PROGRAMS

OFFICE OF SPACE SCIENCE AND APPLICATIONS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C. 20546

August 25, 1965

In Reply Refer To: ST-1/JJK

(Initiating Letter)

One of the most challenging of the potential applications for communications satellites is their use for direct broadcasting of aural and visual programs to the home receiver. The National Aeronautics and Space Administration plans to undertake studies of the technical feasibility of such applications. In doing this, it will be necessary to identify and examine in detail many technological factors.

Among the more important of these factors is frequency utilization. Frequencies currently available for domestic and international broadcasting which might be used for satellite broadcasting lie between 15 and 900 mcs. Is any portion of this range optimal for satellite broadcasting? If not, what other frequencies are suitable and potentially available?

In answering such questions, trade-offs must be considered among such technical factors as home receiver sensitivity, home receiver antenna gain and directivity, spacecraft primary power, spaceborne transmitting tube technology, spacecraft antenna size and directivity, and the influence of the propagation medium.

Another possible application for communications satellites is for distributing educational or entertainment program material to specially designed receiving facilities. For this service frequencies above 900 mcs could also be considered. Trade-off studies would establish the minimum performance criteria for the receiving stations in such a service.

We would like to collect and review all available information bearing on frequency utilization for satellite broadcasting, to help in assessing the intrinsic feasibility, and in deciding what problem areas should be emphasized in future studies. At the same time, we would like to bring together people who have been concerned with certian specialized aspects of the subject, both to give others the benefit of their expertise and to acquaint them with technology in other specialized areas.

The approach we would suggest is that each organization which has been active in this area prepare a compendium of information on frequency utilization, in terms of one or more of the topics listed in the enclosure. Each organization would then present a summary of its compendium at a brief colloquium, at which copies of the compendium would be distributed.

It is proposed to hold the colloquium here in Washington, tentatively on October 7th, and it would be appreciated if you would participate. We would expect about 30 people to attend, and would suggest that you provide at least that number of copies of your compendium. It should be understood that participation is voluntary and that no cost will accrue to NASA as a result of such participation.

Please let us know if you will participate, and let us have the names of the persons expected to attend. Please contact Mr. John J. Kelleher of my office, telephone 202-963-6974.

Sincerely yours,

Leonard Jaffe
Director
Communication and Navigation Programs
Office of Space Science & Applications

Enclosure

LIST OF TOPICS*

Frequency allocations

Spacecraft antennas

Spacecraft primary power

Spacecraft transmitters

Ground-to-spacecraft program link

Propagation considerations

Ground receiver sensitivity

Ground antenna characteristics

Feasible improvements in home receiving installations

1. minimal
2. moderate
3. state-of-the-art

*These topics should be considered in regard to both direct broadcasting and program distribution services.

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INTRODUCTION

Leonard Jaffe

Office of Space Science
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Under the Space Act, NASA has responsibilities for developing the technology required for a broad-based capability for operations in space and for the development of practical space applications. Within this framework, the Communication and Navigation Program Office has the responsibility to study the needs for and also insure that the technology for future communication and navigation systems is developed.

It is obvious to all of you, otherwise you would not be here, that the use of satellites for direct broadcast purposes or certain distribution services for aural and TV material is a technical possibility. We have been studying various aspects of aural and television broadcasting. It may be desirable for NASA to perform additional studies in the area of direct as well as distribution type systems to fully understand the status of technology required.

Of primary concern, obviously, are the potential frequency areas which should be investigated. Mr. Kelleher, your Chairman for today, prepared this chart summarizing the current ITU situation in this area. As you can see, it does not provide too much real information on the question of where one should look specifically for technology and components. However, there has been a considerable amount of work relating to the various aspects of this frequency problem, and this leads us to the purpose of this meeting.

First, we wanted to get the people together who have been working in this field. Second, we wanted to get a consolidated expression of the thought that has gone on in the area with a view toward identifying existing and needed technology, and to record everyone's thoughts on technically possible frequency areas. We have intended that this meeting be primarily a fact-finding meeting rather than a problem-solving session.

One point I want to make absolutely clear, lest there be some misinterpretation of the purpose of this meeting, is that NASA does not now have a program to develop such satellites. We recognize the many policy questions involved in any determination as to the desirability of such an undertaking, and we recognize also the many serious questions which can be raised regarding the need for such devices or the particular uses to which they might be put. It is not our intention to discuss these questions here today. We are here to discuss the technical factors I mentioned and I will ask you all to refrain from making presentations on

FREQUENCY AVAILABILITY

CURRENT ITU POSITION -- PERMITS EXPERIMENTATION IN ANY BAND, INCLUDING BROADCASTING, ON PREARRANGED (RR 118) OR NONINTERFERENCE BASIS (RR 115, 700)

-- NO EXPLICIT PROVISIONS FOR EXPERIMENTAL SPACE BROADCASTING

-- ENCOURAGES CCIR TO CONTINUE STUDIES ON TECHNICAL FEASIBILITY, SHARING (Rec 5A, EARC)

BROADCASTING BANDS IN EXISTING ITU ALLOCATIONS --

HF	5.9 - 6.2	Mc/s	(49 m)	VHF	41 - 88	Mc/s	(mainly TV)
	9.5 - 9.8	"	(31 m)		88 - 108	Mc/s	(mainly FM)
	11.7 - 11.97	"	(25 m)		174 - 216	Mc/s	(TV)
	17.7 - 17.9	"	(19 m)				
	21.4 - 21.7	"	(15 m)	UHF	470 - 890	Mc/s	(TV)
	25.6 - 26.1	"	(11 m)				

the nontechnical questions. It may be necessary to refer to a hypothetical user to define an approach, but beyond that I am asking you all to stick to the technology, and if your prepared presentations depart, would you please make appropriate deletions.

I would like to express not only NASA's appreciation but to extend my personal thanks for the time and effort you have expended in participating in this meeting. I am sure that the discussions today, and the material you have prepared, will be of great value to NASA, and of mutual benefit to all of you.

Jack Kelleher will moderate today's program, so I will turn the meeting over to him now.

COMMUNICATIONS SATELLITE CORPORATION

F. J. D. Taylor and R. G. Gould

Frequency Aspects of Satellite Broadcasting

Summary of Presentation

Two types of service were discussed:

1. Broadcasting - Satellite Service (Reference 84AP of Final Acts of E.A.R.C., Geneva 1963)

2. Communication-Satellite (Education) Service (Reference 84 AG of Final Acts of E.A.R.C., Geneva, 1963)

NOTE: If Type 2 can be categorized as a communication satellite service, then use could, presumably, be made of radio frequencies allocated to that service.

As frequency allocations for broadcasting-satellite service have not been made, it is desirable to examine first if use can be made of frequencies allocated to the broadcasting service and, second, if frequencies not so allocated would be preferable and likely to be made available. (Refer to Mr. Taylor's remarks during open discussion, p.58.)

Bands above 40 mc which are available for broadcasting in all regions are:

54 - 68 mc
88 - 100 mc
174 - 216 mc
470 - 585 mc
610 - 890 mc
11.7 - 12.7 Gc

Although it might be preferable to use the lower frequencies in certain coverage areas (India, for example) there appear to be arguments in favor of using 610-890 mc for the U.S. It is undesirable to go to higher frequencies because:

1. No frequencies have been allocated for this service.

2. Home receivers would be more complex and expensive.

3. More accurate antenna pointing would be required, plus higher feeder losses.

For the communication-satellite (education) service, if 84 AG applies, frequency allocations are already available, these lying in the 4 (up), 6 (down), 8 (up), and 7 (down) Gc bands. The foregoing assumes geostationary satellites. Certain exclusive bands were allocated by the E.A.R.C., namely 7.25-7.3 and 7.975-8.025 Gc, but it is unlikely that these would be suitable for this projected service.

* * * * *

During the discussion period which followed, Mr. Taylor stated that if the educational service can be considered as a point-to-point service, use might be made of the 4-Gc and 6-Gc bands, but he indicated that these bands might become quite congested. In addition, with respect to flux density, the existing limits as imposed by the E.A.R.C. are quite stringent and might not be consistent with reasonably low cost ($100,000) education receiving equipment. For this reason it might be necessary to seek special frequency allocations.

Mr. Allen stated, referring to distribution directly to schools, that even the use of an 80-foot dish at the school would not solve the coordination problem with respect to microwave interference.

Mr. Taylor clarified his interpretation of the educational service, stating that service directly to schools might be much nearer a broadcasting-satellite service, and that his impression was a service which would be used to feed communities rather than individual schools. In the latter case, a station could be sited 10-15 miles away in order to facilitate the coordination with other services and could perhaps use one receiving antenna per town.

FAIRCHILD-HILLER CORPORATION

M. J. Minneman

Relationship Between Transmitter Power and Potential Receiver Coverage in Direct Voice Broadcasting

Summary of Presentation

Two satellite altitudes are considered: 22,300 statute miles (equatorial synchronous) and 800 statute miles. The coverage, antenna 3-db beamwidths, and gain are as follows:

Altitude	Satellite Antenna B. W.	Satellite Antenna Gain	Horizon Coverage
800 mi.	113	6.5 db	17% of hemisphere
22,300 mi.	18	22.0 db	85% of hemisphere

An analysis is made at four frequencies, 10, 30, 100 and 700 mc. The requirements for adequate reception vary with the ambient noise present; therefore, the power level transmitted from the satellite will determine the percent of receiving sets receiving satisfactory signals. It has been assumed that receivers would be equally distributed over the area of geographic coverage. A representative path from satellite to earth which would encompass half of the receivers in the coverage area is used for calculation purposes. The satellite antenna cone angle for this path is 109 degrees for 800 miles and 15 degrees for 22,300 miles.

The ionospheric (D-layer) losses are as follows:

Frequency(mc)	Attenuation (db) 800 miles	Attenuation (db) 22,300 miles
10	10.0	6.4
30	1.2	.7
100	0.1	.1
700	0	0

Using the above attenuation values, the power density in watts per square meter at the earth for 1 watt isotropic transmission is as follows:

	Power Density (db watts/m^2)	
Frequency(mc)	800 miles	22,300 miles
10	-147 db	-149 db
30	-138	-144
100	-137	-143
700	-137	-143

To determine the required signal level, the receiving locations have been divided into three equally numbered groups: rural, suburban, and urban locations. Within each area it is assumed that 80 percent of the potential listeners would be satisfied if the signal were 26 db above the noise level.

Figure 1 shows the required field strength versus percentage of receivers having satisfactory signals. An increase from 10 to 90 percent requires approximately a 50-db increase in signal level. The transmitted power required versus percentage of receiver coverage is shown in Figure 2. It is shown that at synchronous altitude there is far greater coverage than at 800 miles and that the 100-mc case requires the least power. With respect to frequencies, we are tending to favor the 100 and 700 mc regions, and for 50 percent coverage about 10 kw would be required.

* * * * *

During the question period Mr. Andrus inquired as to the approach for obtaining 22-db antenna gain at the low frequencies. Dr. Minneman stated that an antenna with a diameter of 40 feet would be required for 100 mc and 130 feet for 30 mc. He added that 1000-watt solar cell arrays, sun-oriented, would probably be as small as 100 square feet.

* * * * *

NOTE: Dr. Minneman invited comments during his presentation as to whether regulations would permit sound broadcasting alone on the sound channels in the UHF TV bands. No comments.

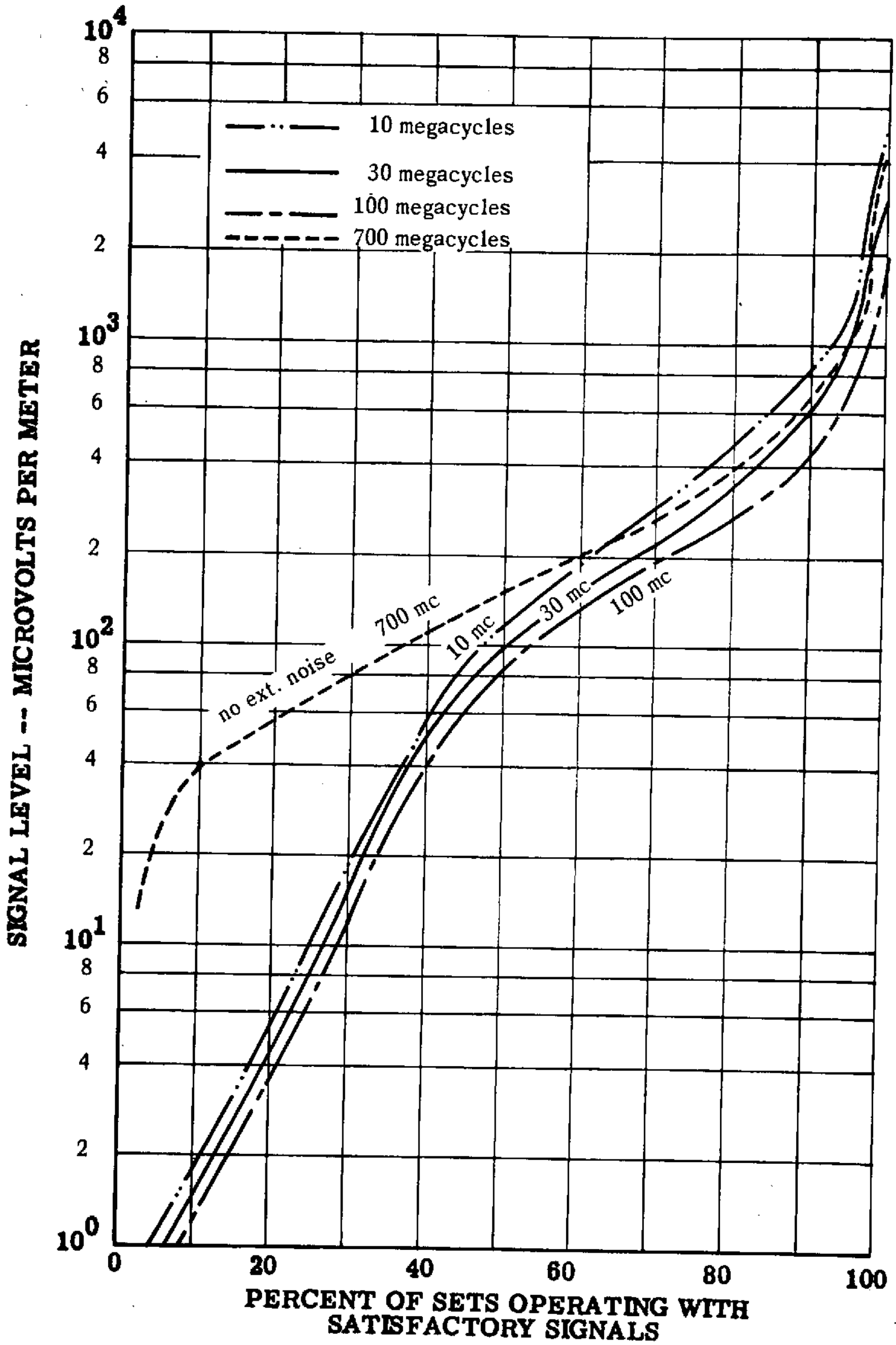


Figure 1. Field Strength Requirements

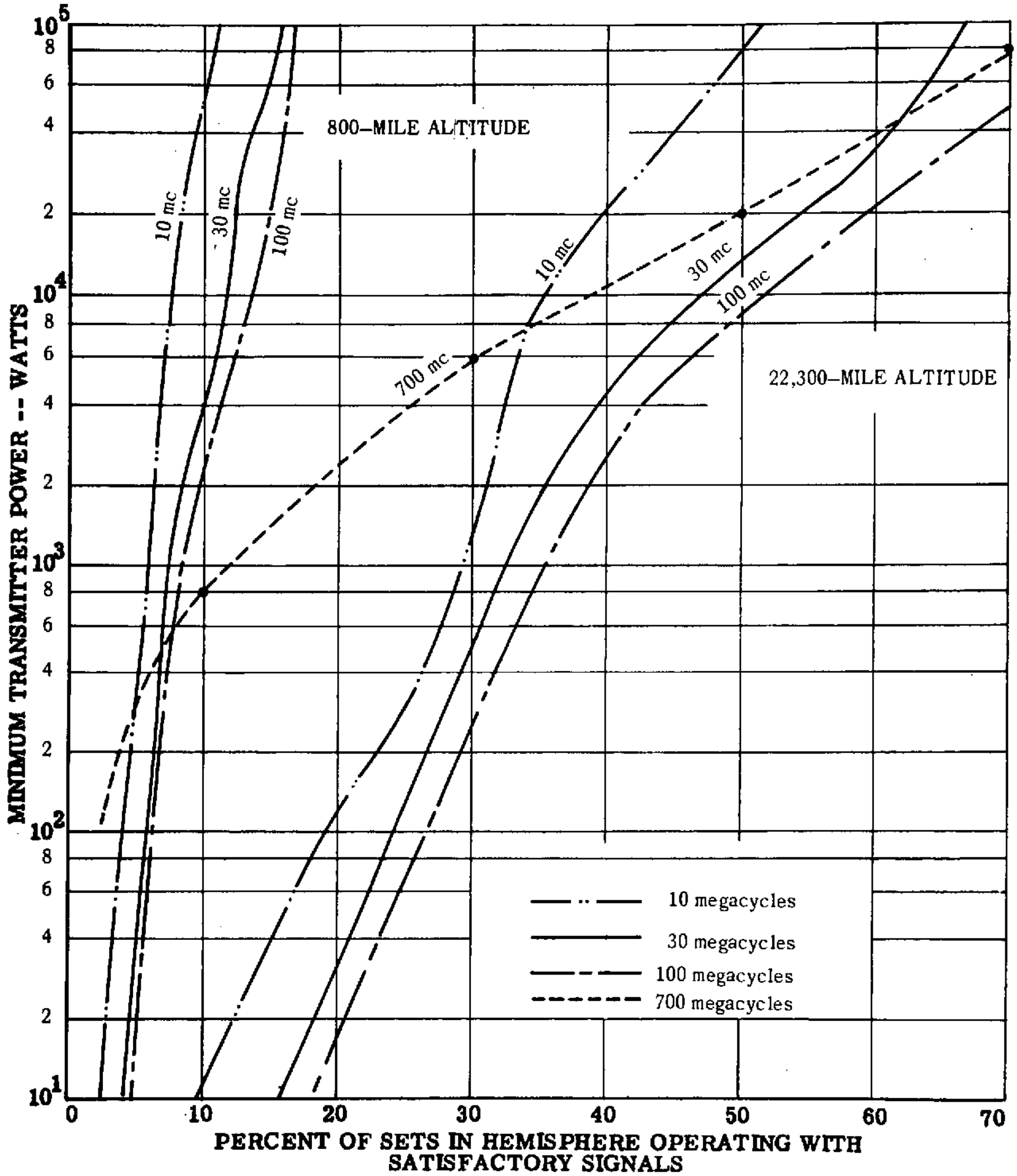


Figure 2. Required Transmitter Power

GENERAL ELECTRIC COMPANY

R. Haviland

Broadcasting from Satellites - Frequencies, Standards and Interference

Summary of Presentation

Figure 1 develops a relative frequency value for TV broadcasting. The assumptions for each of the factors considered are given. The composite indicates that the use of frequencies between 100 and 10,000 mc should be possible. The 11-Gc band in the international allocations for broadcasting is apparently not presently used and must be considered as one of the possibilities. For educational TV there are some U.S. bands which might be made available, subject to negotiations about interference, in particular, the 2500-2690 mc educational TV band. This can be shared at least under some conditions.

In considering existing reception quality for TV, Figure 2 shows the percentage distribution for both the TASO and the FCC New York studies. The TASO evaluation method was used. The effect of distance from a terrestrial station is shown in Figure 3. Recognizing that it will be some time before the highest standard will be achieved for direct TV broadcasting it is proposed that a three-standard system be established as follows:

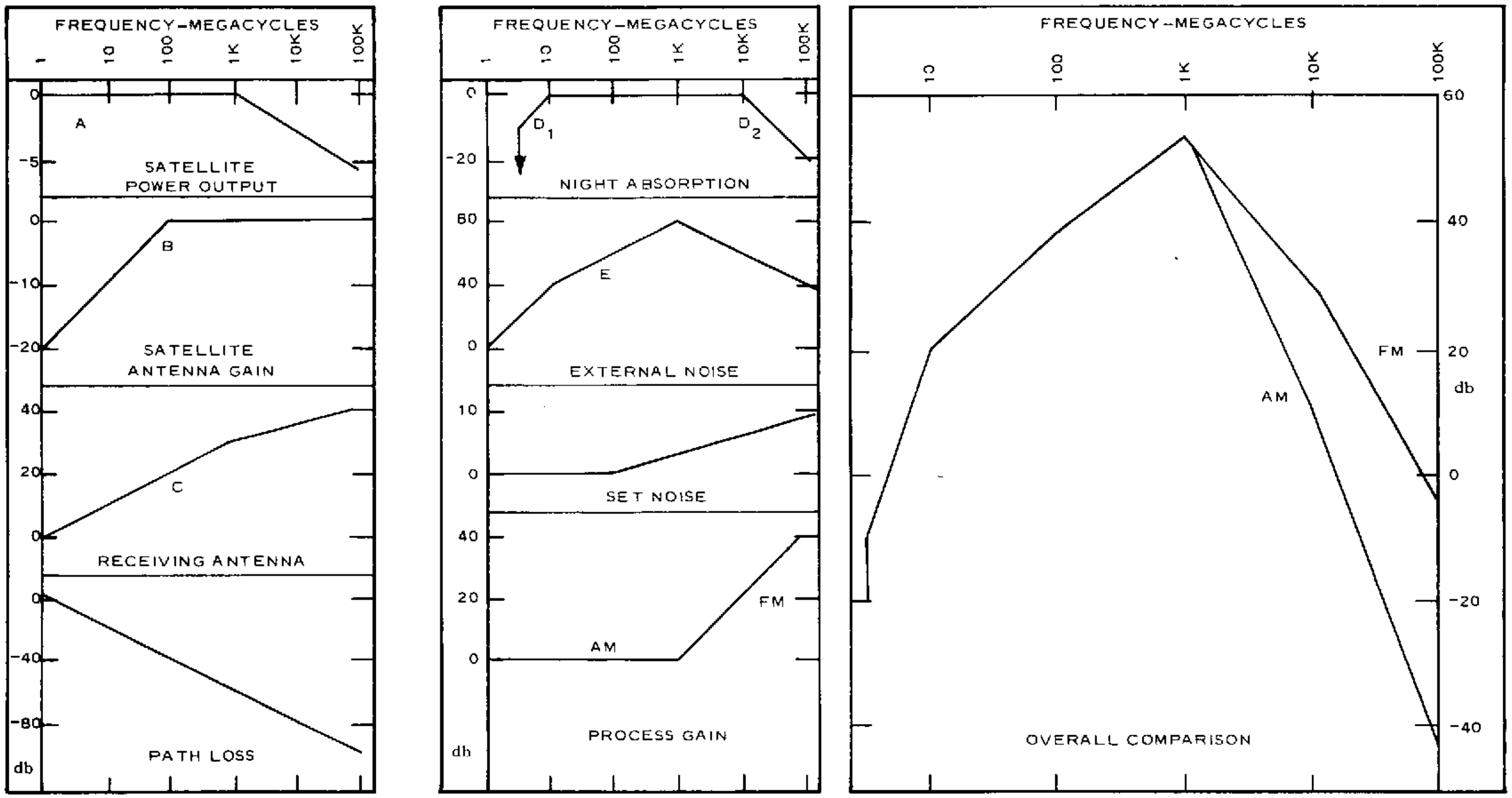
- Grade P - Capable of providing the highest quality of reception. This is interpreted as providing at least Grade 1 service with good outdoor antenna installations and Grade 2 service with reasonable indoor antenna.

- Grade Q - Capable of providing a high quality of reception with modest installation cost. This is interpreted as providing Grade 1 service with good outdoor antennas.

- Grade R - Capable of providing good quality of service with reasonable installation cost. This is interpreted as providing Grade 2½ with good outdoor antenna.

These proposed signal grades must be translated into engineering criteria assuming a standard receiving installation. The assumptions are given in Table 1.

NOTE: With respect to the classes of service Mr. Haviland expressed the opinion that in accordance with the radio regulations the point-to-point service is the only type which Comsat is now in and that TV distribution to schools and networks falls within the definition of Special Services.



A–CONSTANT OUTPUT PER KILOWATT INPUT UP TO 1 Gc
B–CONSTANT GAIN ANTENNA DOWN TO 100 mc –CONSTANT AREA BELOW.
C–HIGH END GAIN DUE TO INCREASED PRECISION AND IMPROVED TRANSMISSION LINES. APPROXIMATELY CONSTANT COST.
D-1–IONOSPHERIC. 2–ATMOSPHERIC AND RAIN.
E–ATMOSPHERIC, COSMIC, AND QUANTUM NOISE

Figure 1. Relative Frequency Value - TV Broadcast

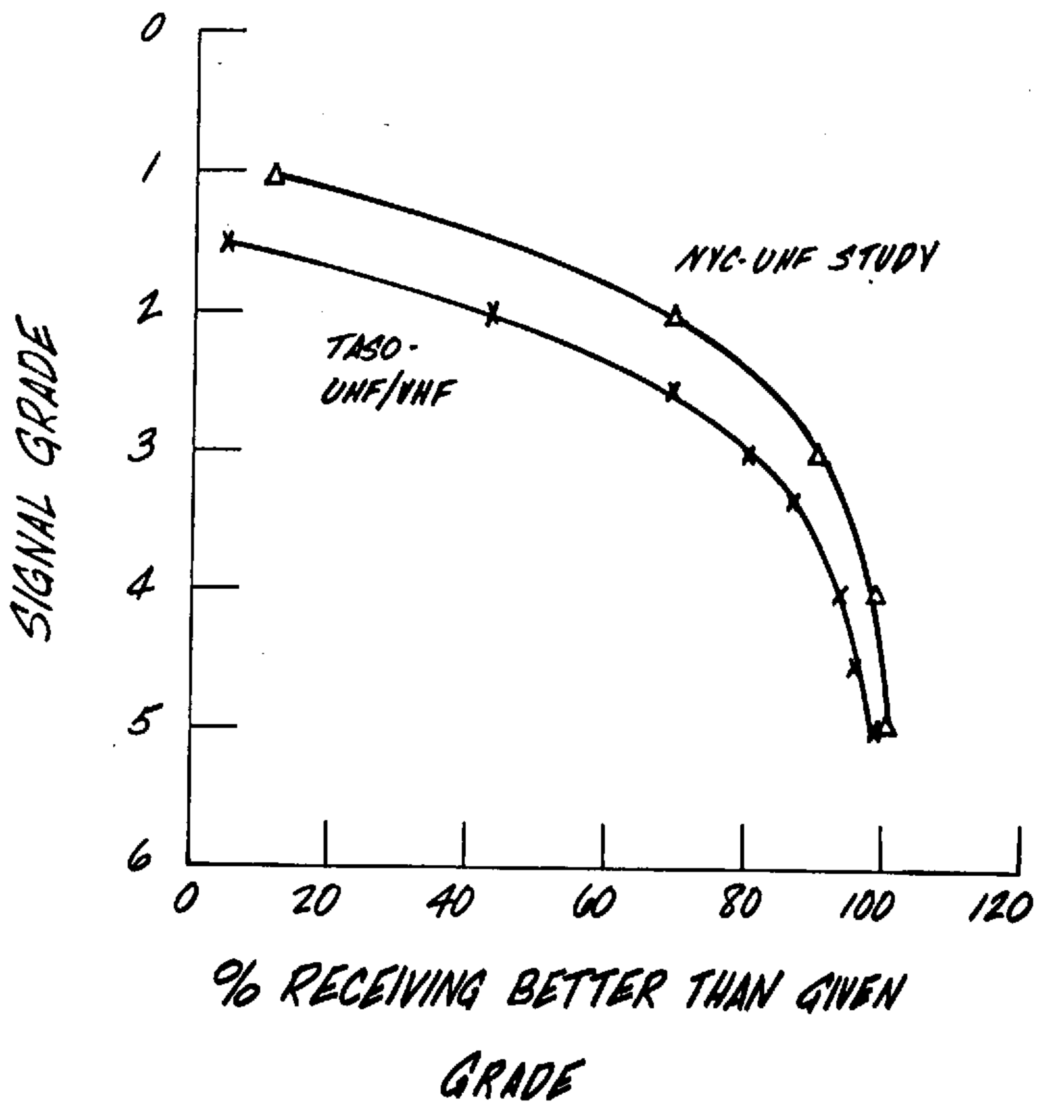


Figure 2. Existing Service Quality

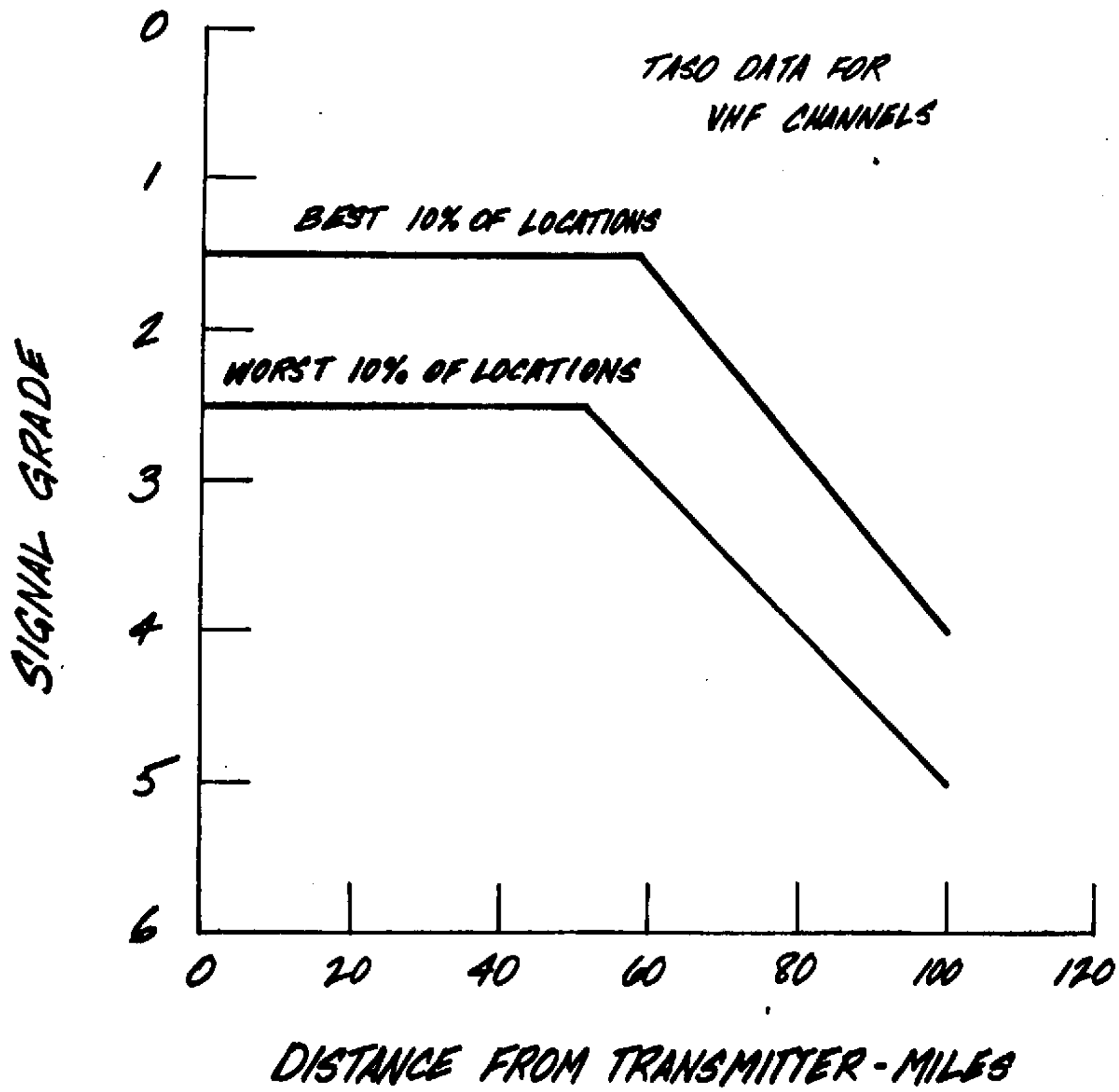


Figure 3. Effect of Distance from Station

TABLE 1. ASSUMPTIONS

		Channel 2	Channel 7	Channel 31
Receiver NF		7 db	7 db	10 db
Antenna:	Outdoor	+3.0 db	+6 db	+18 db
	Indoor	-3.0 db	0.0	+12 db
Building Absorption		15 db	18 db	22 db
Outdoor Antenna Line Loss		-2 db	-2 db	-2 db

The preceding assumptions lead to the signal levels required in microvolts/meter, as shown in Table 2 for outdoor antennas.

TABLE 2. SIGNAL LEVEL - μV/M

		Channel 2	Channel 7	Channel 31	Remarks
Grade P:	Video	1020	2600	8500	≈ FCC
	Aural	325	830	2700	Grade A
Grade Q:	Video	450	1000	1000	≈ FCC
	Aural	145	316	316	Grade B
Grade R:	Video	90	200	200	New
	Aural	29	64	64	

Proposed standards for FM and HF/AM are given in Table 3.

TABLE 3. SIGNAL LEVEL - μV/M

Grade	FM	HF/AM	Remarks
P	1000	200	
Q	250	40	New for
R	50	6.3	HF/AM

The signal-to-noise for educational TV should be at least 40 db and probably as high as 50 db, with a picture resolution of at least 525 lines.

The question of interference between terrestrial and space stations on the same frequency must be seriously considered because of the mutual effects on the coverages attainable. The required signal/interference ratios are given in Table 4.

TABLE 4. REQUIRED SIGNAL/INTERFERENCE RATIOS

	Tolerable	Negligible
TV		
Normal tolerance	45 db	60 db
Normal offset	30	45
Precise offset	20	35
FM		
Normal design	20 db	28 db
AM		
Normal design	20 db	45 db

An important consideration is the discrimination pattern of the receiving antenna. Although the CCIR pattern discrimination curves have been used in studies to date, they might be improved somewhat without too much cost. In addition a receiving antenna pointed at a synchronous satellite would have an appreciable elevation angle for most areas of interest. For example, with a synchronous satellite at 100 degrees west longitude, Rio would have a 20 degree elevation angle. Interference can be further reduced by the use of circular polarization from the satellite and reverse circular polarization from the terrestrial station. This matter needs additional study.

The general conclusions with respect to frequency selection are:

- 10-30 mc - world or regional AM service for special use
- 88-108 mc - FM world system on a shared or clear channel basis
- 175 mc - rural world TV
- 700-900 mc - world/regional TV
- 11 Gc band - future potential for small-area local TV.

It would appear that there is a reasonable possibility of using existing allocations - they are technically feasible.

* * * * *

During the question period, Mr. Allen stated, with respect to the new standards proposed, that separate studies have not been performed nor have they been discussed in detail with Mr. Haviland.

Mr. Jacobs pointed out that while a system might be designed for a minimum satisfactory signal, there is a question as to whether the minimum acceptable signal will in fact be strong enough to attract an audience in a competitive atmosphere.

Mr. Haviland noted that as of December 1963, in the American and European systems, there were very few stations at the upper end of the UHF TV band and that if an exclusive channel is preferred, an early start should be made to clear one or two channels for the space service.

HUGHES AIRCRAFT COMPANY

Dr. H. A. Rosen

Direct Broadcasting Satellite for

Educational Television - ETV

Summary of Presentation

We believe that for the purpose of direct broadcasting to schools, the best system is a spin-stabilized, synchronous satellite, having a high power active repeater, broadcasting in the low microwave bands and using FM as a method of modulation. Synchronous satellites will minimize the cost of the receiving antenna, and spin stabilization will provide the least expensive way of achieving the necessary attitude and orbit control precision. The detailed design of such a satellite was submitted to NASA in the form of an unsolicited proposal.

The microwave region was selected in order to provide an essentially unlimited number of channels. In this band, use can be made of direction as well as frequency for signal discrimination. Considering just the band between 1500 and 4200 megacycles and beamwidths achievable with 6-foot dishes for receiving, there is probably room for 5000 channels even using FM. FM does not particularly restrict the number of channels which can be assigned because, although each of many channels require more bandwidth, the improved selection capability relative to AM permits narrower space geometry, and thus more satellites can be usefully employed.

The parameters of the system were chosen based on current technology. Referring to Table 1 and model No. 306, in the Atlas-Agena launch series we gain a factor of 10 in payload weight at very little increase in cost.

In the case of model number 306, most of the payload power and weight is allocated to the experiments. However, in model No. 307 where all of the payload is used for the communication system it is possible to have an ERP of 40 dbw using a microwave power of 100 watts and an antenna gain of 100, corresponding to illuminating 1/6 of the earth's surface. With an antenna gain of 30 db, a coverage of 1/60 of the earth's surface is provided and a country the size of India could be served.

The 100 watts of microwave power is obtained by operating low power TWT's in parallel. The use of multiple tubes allows each antenna to be driven separately. This has the advantage of minimizing the microwave loss which occurs when the tube precedes the antenna phase shifting elements as in the case of an electronically despun antenna which will be used in the model No. 306. In model No. 307 there will be 16 TWT's.

TABLE 1. SYNCHRONOUS COMMUNICATION SATELLITES

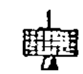
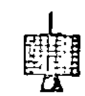
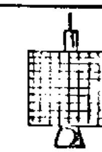
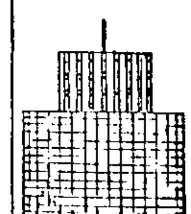
HUGHES NO.	NAME	LAUNCH DATE	USE	DC SOLAR POWER, WATTS	TRANSMIT ANTENNA GAIN		EFFECTIVE RADIATED POWER		BAND-WIDTH, mc	TELEPHONE CIRCUITS OR TV	Δ VELOCITY, fps	WEIGHT, lbs	LAUNCH VEHICLE	RELATIVE SIZE
					TIMES	db	WATTS	dbw						
301	SYNCOM 2	1963	NASA TEST-D.O.D.	30	3.5	5.4	5	7	0.5, 5.0	50	300	150	DELTA	
301	SYNCOM 3	1964	NASA TEST-D.O.D.	30	3.5	5.4	5	7	5.0, 13.0	50	500	150	TAD	
303	EARLY BIRD	1965	CSC ATLANTIC TRUNK	45	8.0	9.0	32	15	50	240	600	150	TAD	
306	APPL. TECH. SAT. ATS-B	1966	EXPMTS	200	50.0	17.0	320	25	25	1000	800	1550	ATLAS AGENA	
307	—	1967	EDUCA-TIONAL TV	550	100-1000	20-30	10,000-100,000	40-50	25	SINGLE TV AND MULTI-LANGUAGE VOICE	>2,000	1550	ATLAS AGENA	

Figure 1 shows a typical ground terminal for ETV. The antenna is a 6-foot dish and includes a parametric amplifier, uncooled front end and an IF amplifier-discriminator.

The following recommendations are proposed with respect to direct broadcast frequency allocations:

1. The cleanest solution would be the designation of an exclusive band for this service. One recommendation is that some portion of the Aeronautical Radionavigation band (1540-1660 mcs), approximately 30 mcs be committed. The spatial separation of satellites, especially synchronous satellites, would allow many TV channels to be provided with such an allocation. In this case the power limitations as currently (provisionally) recommended in the shared band of 3400-4200 mc would not be applicable.

2. A second possibility is sharing on a no-possible interference basis anywhere in the 1-10 kmc region. In addition to the above, 2450-2500 mc (remote TV pickup band) should be explored.

3. A third possibility is the use of the currently designated communication bands which are shared with ground microwave systems (power limitations apply). For wideband FM, the satellite ERP may not exceed approximately 1600 watts (-130 dbw/m^2) at the earth's surface. This would require 18-foot antennas for satisfactory reception. Smaller antennas would require ERP's in excess of 5000 watts.

In the booklet distributed, some of the geometric aspects involved in the matter of frequency allocations are illustrated. I personnaly feel that not nearly enough attention has been given to the geometric discrimination, directional discrimination in frequency allocation. In the case of stationary satellites, it is the most important parameter to achieve signal discrimination.

* * * * *

During the discussion Mr. Allen informed the meeting that the U.S. study group is now proposing to modify recommendation No. 406 of CCIR, which affects the pointing and effective radiated power for microwave systems, in order to give some recognition of the problem of constant interference to the equatorial synchronous orbit.

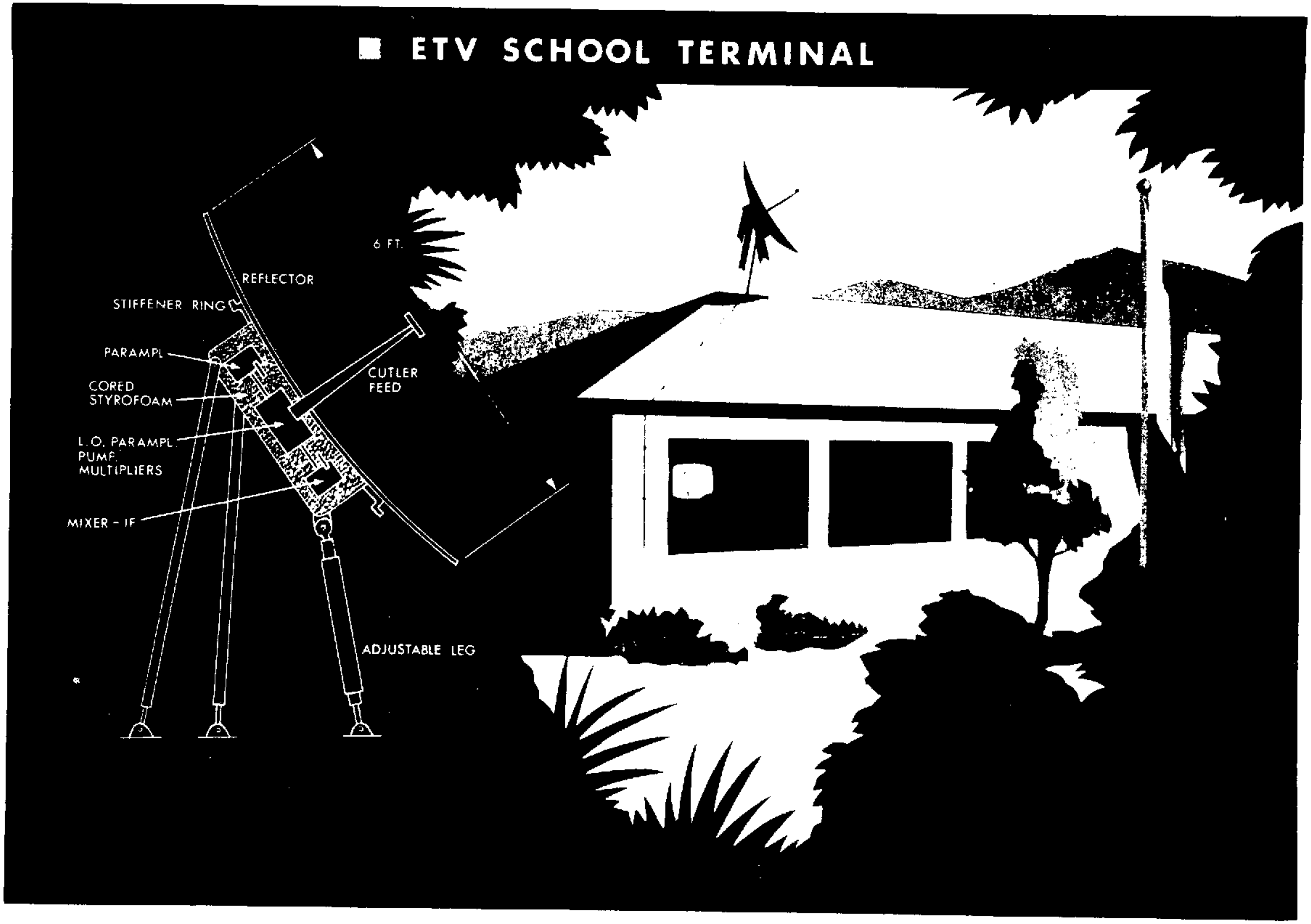


Figure 1. ETV School Terminal

ITT FEDERAL LABORATORIES

D. E. Hershberg

1. Direct Broadcasting to Home Receivers

2. TV Satellite Distribution Cost

1. Direct Broadcasting to Home Receivers

The information in Table 1 is supported by the following assumptions:

- Receiver transmission line - 30 feet, with diameter of 0.5 inches at the higher frequencies and 0.25 at the lower frequencies.
- Receiving antenna at lower frequencies - a Yagi with gain of 8 db and not exceeding 30 db for the high frequencies (5-degree beam).
- Satellite antenna gain of 16 db at the limits of coverage area.
- Normal receiver noise figures used; however, at the higher frequencies, the noise figure may be reduced to 5 db by the use of a low-noise amplifier.
- In estimating the level of man-made noise, a typical suburban area and a simple dipole receiving antenna have been used.

Figure 1 is a plot of the results contained in Table 1, based on the above assumptions.

2. TV Satellite Distribution Cost

Space Segment Cost

The following parameters are used:

1. Eight TV channels.
2. Triaxial stabilized satellites with station keeping.
3. Probability of service for five years, 0.5.
4. Coverage of Continental U.S.A. only.
5. One operating satellite only.

TABLE 1. FM SOUND BROADCASTING TO HOME RECEIVERS

FREQUENCY, mc		100.	300.	650.	1000.	4000.	10000.
Path Loss (db) Slant Range 25000 S.M.		-165	-175	-181	-185	-197	-205
Transmission Line Loss, Receiver (db)		-1.5	-2.	-2.3	-2.6	-6.2	-13.2
Receiving Antenna Gain (db)		+8.0	+8.	+14.	+18.	+30.	+30.
Satellite Antenna Gain (db)		+16.	+16.	+16.	+16.	+16.	+16.
System Loss		-142.5	-153.	-153.3	-153.6	-157.2	-172.2
Noise Levels (°K)	Receiver	1200.	1900.	3000.	3600.	7500.	9500.
	Cosmic	5400.	360.	136.	100.	---	---
	Man-Made	75000.	75000.	1500.	600.	---	---
Total Noise Level (dbm) bw 200 kc		-97.	-107.	-109.	-109.	-107.	-106.
Required Carrier Level (dbm) for C/N = 20 db		-77.	-87.	-89.	-89.	-87.	-86.
Required Transmitter Power (dbm)		+65.5	+66.	+64.3	+64.6	+70.2	+86.2
Required Transmitter Power (kw)		3.5	4.	2.7	2.9	10.5	415.

NOTES: For TV, the Rx would have a bandwidth of 4 mc and would require C/N = 30 db. Power required for TV would be about 23 db greater than that for FM sound broadcasting.

Tx power requirements do not take into account ionospheric and atmospheric absorption, fading or terrain effects.

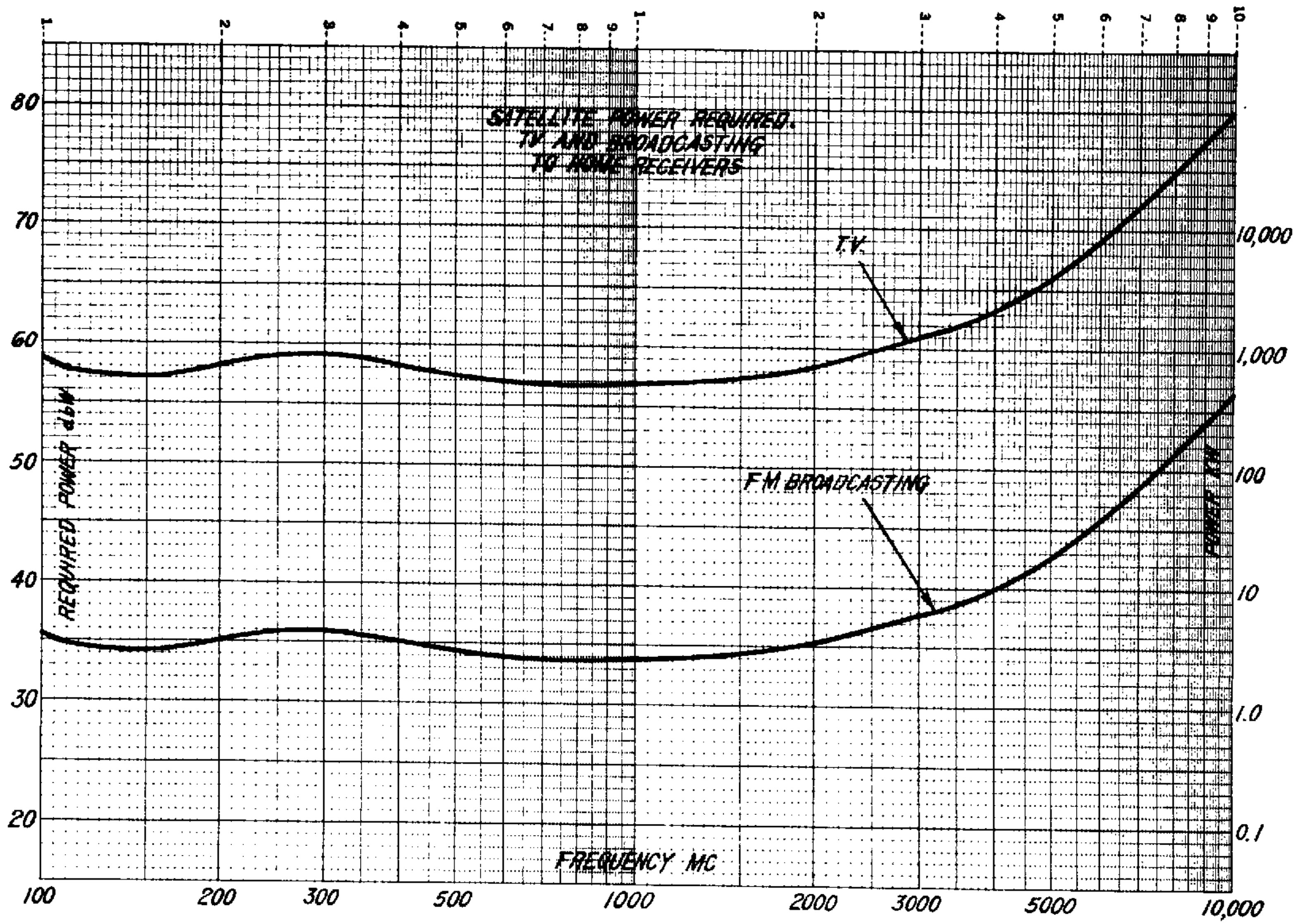


Figure 1. Satellite Power Required. TV and Broadcasting to Home Receivers

The cost of the space subsystems shown in Table 2 includes development, establishment, and replenishment over a ten-year period.

TABLE 2

		Cost in Millions of Dollars		
System	ERP (dbm) Per Channel	Launch + Satellite	Replenishment	Annual Cost
1	52	15.045	12.7	2.77
2	64	24.045	22.0	4.60
3	74	42.045	54.2	9.62

Ground Terminal Cost

The following parameters were used:

1. Manual pointing.
2. Parabolic antenna.
3. Receive-only capability.
4. Phase-locked-loop demodulation.
5. Peak-to-peak signal to RMS noise 45 db.
6. 4-mc baseband.
7. 200 ground terminals.
8. Ten-year useful life.
9. 4-Gc downpath frequency.

Figure 2 is a curve of ground station costs versus the ERP of the satellite for a synchronous satellite and 200 ground terminals. Operating costs are not included.

Conclusions

Using the above parameters, the optimum system appears to be a satellite with an ERP/channel of approximately 64 dbm and an Atlas-Agena launch. The technology to develop a three-axis stabilized satellite, station-kept in a 24-hour orbit, will be available in the near future. The total yearly system cost is competitive with the present landline facilities.

* * * * *

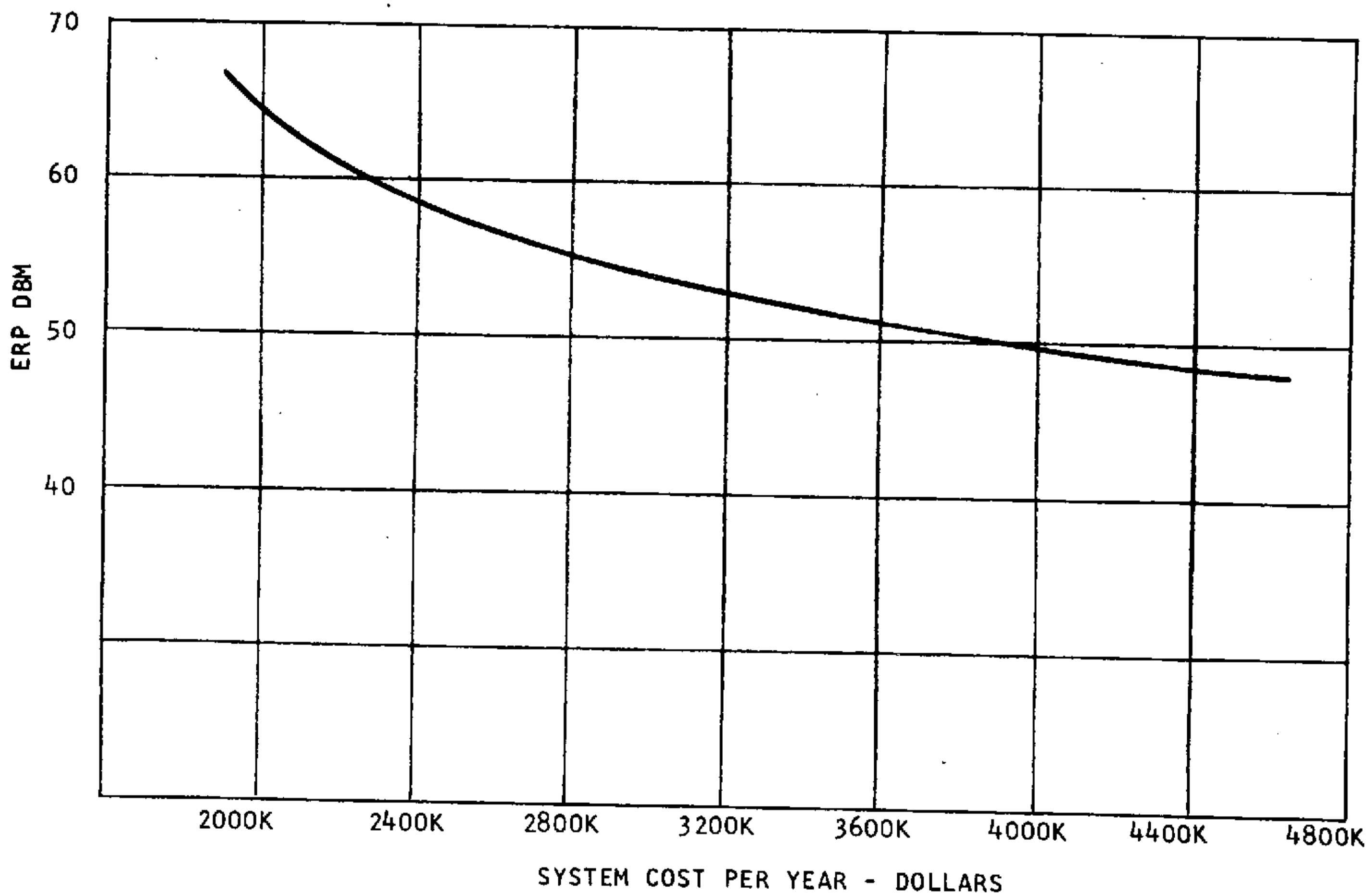


Figure 2. Satellite ERP Versus Cost of Ground System Per Year, 200 Stations

During the discussion which followed, Mr. Haviland noted that the FCC-New York City studies indicate that man-made noise is less severe than previously assumed, resulting in a 10 percent chance that the signal will be degraded one grade or about 6 db. In addition he noted that the ITT figure for TV satellite power required is about 10-20 db higher than his calculation. Mr. Allen pointed out that, in dealing with noise, if use is made of a mobile survey some correction factor should be applied for house-top installations since the largest component of man-made noise seems to be automobile ignition noise which occurs at street level.

JANSKY & BAILEY SYSTEMS ENGINEERING DIVISION

ATLANTIC RESEARCH CORPORATION

C. E. Sampson

Cost of Receiving Systems vs. Satellite ERP

Summary of Presentation

The paper discusses a comparative analysis of the manufacturing cost of various combinations of receiving equipment capable of direct home reception of TV signals from a satellite in a synchronous orbit. The work is being done for NASA. The frequency range covered is from 0.1 to 10 Gc. The present study is directly related to the determination of the ERP required from a satellite for various signal levels. Emphasis to date has been on the development of an analysis technique. Data have been obtained on the cost of present VHF-UHF tuners and the cost to achieve improvements in present receiver noise figures. In addition, information has been obtained with respect to the cost of various types of receiving antennas.

The basic approach investigates the propagation equation together with receiving system characteristics to determine the required ERP. Figure 1 shows the parameters which are used in the equation, and Figure 2 shows in a general way the frequency dependence of both environmental and receiver parameters. It should be noted that $(S/N)_o$ is the required signal-to-noise <u>output</u> to provide a particular grade of service. Present grades are based on signal strength alone, which might indicate a higher-than-necessary ERP. It is assumed that the antenna will be looking approximately 10 degrees above the horizon with a temperature of 100 degrees Kelvin. Figure 2 indicates that as the receiver noise is reduced to an absolute minimum the proper location in the spectrum becomes important.

In the development of optimum equipment combinations, the important components are N, A_R, L and I. Initially, emphasis will be on the determination of the technique for calculating minimum cost systems for various amounts of ERP. The basic technique is illustrated in Figure 3. In the illustration there are only two equipment parameters which are variable - noise figure and antenna area. It is possible to express the antenna area in terms of noise figure and required satellite power. Thus, it is possible to express C_T as a function of one variable, N. Equation 8 is the result. Differentiating C_T with respect to N (Equation 9), which will provide a minimum cost combination of noise figure N and antenna area A for any desired value of ERP, the optimum value of A can be calculated from Equation 8. The results based on the foregoing for 900 mc are shown in Figure 4.

NOTE: Curves relating manufacturing costs to tuner noise figures and to effective antenna areas were included in the compendium distributed at the colloquium. These cost curves were used to develop equations which relate cost to equipment parameters, and were used in the cost equation of Figure 3.

$$P_T = \frac{F(S/N)_O \, 4\pi \, R^2 \, (KB)}{I} \; \frac{\left[T_A + T_O \, (LN + L - 2)\right]}{A_R} \, \delta$$

OR

$$P_T = \psi \, \frac{\left[T_A + T_O \, (LN + L - 2)\right]}{I \, A_R}$$

WHERE

$\psi = F(S/N)_O \, 4\pi R^2 \, (KB) \, \delta$

P_T = SATELLITE EFFECTIVE RADIATED POWER

WHERE

L = FEEDER LOSS

I = MODULATION IMPROVEMENT FACTOR

N = RECEIVER NOISE FIGURE

A_R = EFFECTIVE ANTENNA AREA

T_O = 290°

T_A = ANTENNA TEMPERATURE

$(S/N)_O$ = REQUIRED RECEIVER SIGNAL-TO-NOISE OUTPUT

B = RECEIVER NOISE BANDWIDTH

F = FADE MARGIN

R = DISTANCE TO RECEIVER

δ = POWER LOSS DUE TO FARADAY ROTATION AND ATMOSPHERIC ABSORPTION

Figure 1. Parameters Used in the Propagation Equation

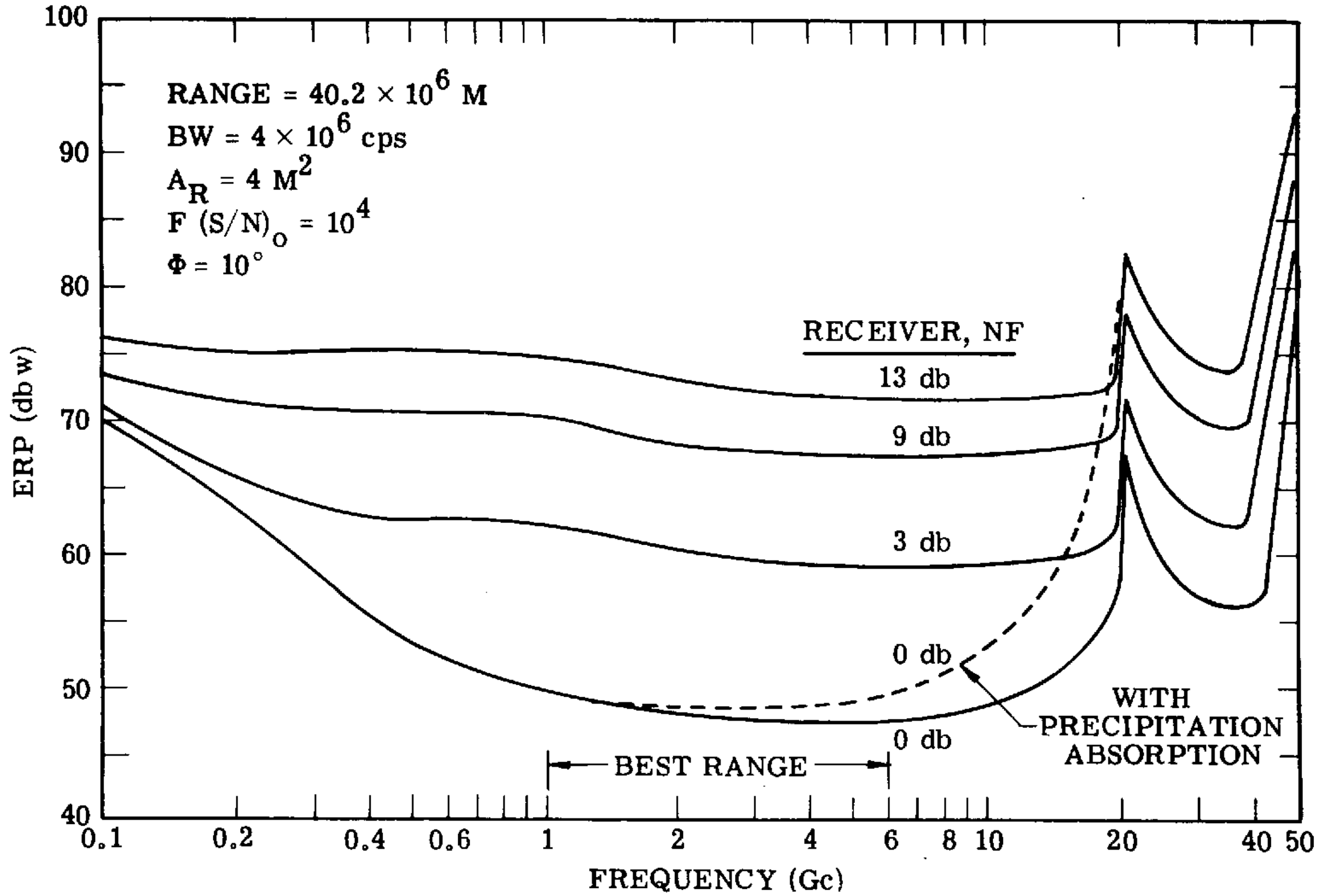


Figure 2. Required Satellite ERP for Good TV Reception

$$\text{TOTAL COST } C_T = C_N + C_A + C_L + C_I \tag{1}$$

$$C_N = 3.7 + 9.3\ (N-1)^{-1.65} \tag{2}$$

$$C_A = 25\ A_R \tag{3}$$

$$C_L = 0.25\ (\text{For } L = 3 \text{ db}) \tag{4}$$

$$C_I = 0\ (\text{For } I = 1) \tag{5}$$

$$A_R = \frac{\psi}{P_T}\left[T_A + T_0\ (LN+L-2)\right] \tag{6}$$

$$\psi = F(S/N)_0\ 4\pi R^2\ KB\delta \tag{7}$$

Thus Equation (1) becomes:

$$C_T = 3.7 + 9.3(n-1)^{-1.65} + 25\frac{\psi}{P_T}\left[T_A + T_0\ (LN+L-2)\right] + 0.25 + 0 \tag{8}$$

ψ May be calculated assuming:

$$F(S/N)_0 = 40 \text{ db}$$

$$B = 4 \text{ Mc}$$

$$T_A = 100^\circ \text{ K (Typical of 900 Mc)}$$

To obtain value of N for minimum cost differentiate Equation (8) and set

$$\frac{\partial C_T}{\partial N} = 0$$

Then

$$N(\text{for minimum } C_T) = 0.026 P_T^{1/2.65} + 1 \tag{9}$$

Figure 3. Illustrative Example of Method for Minimizing Equipment Cost by Optimizing Selection of Antenna-Tuner Combination

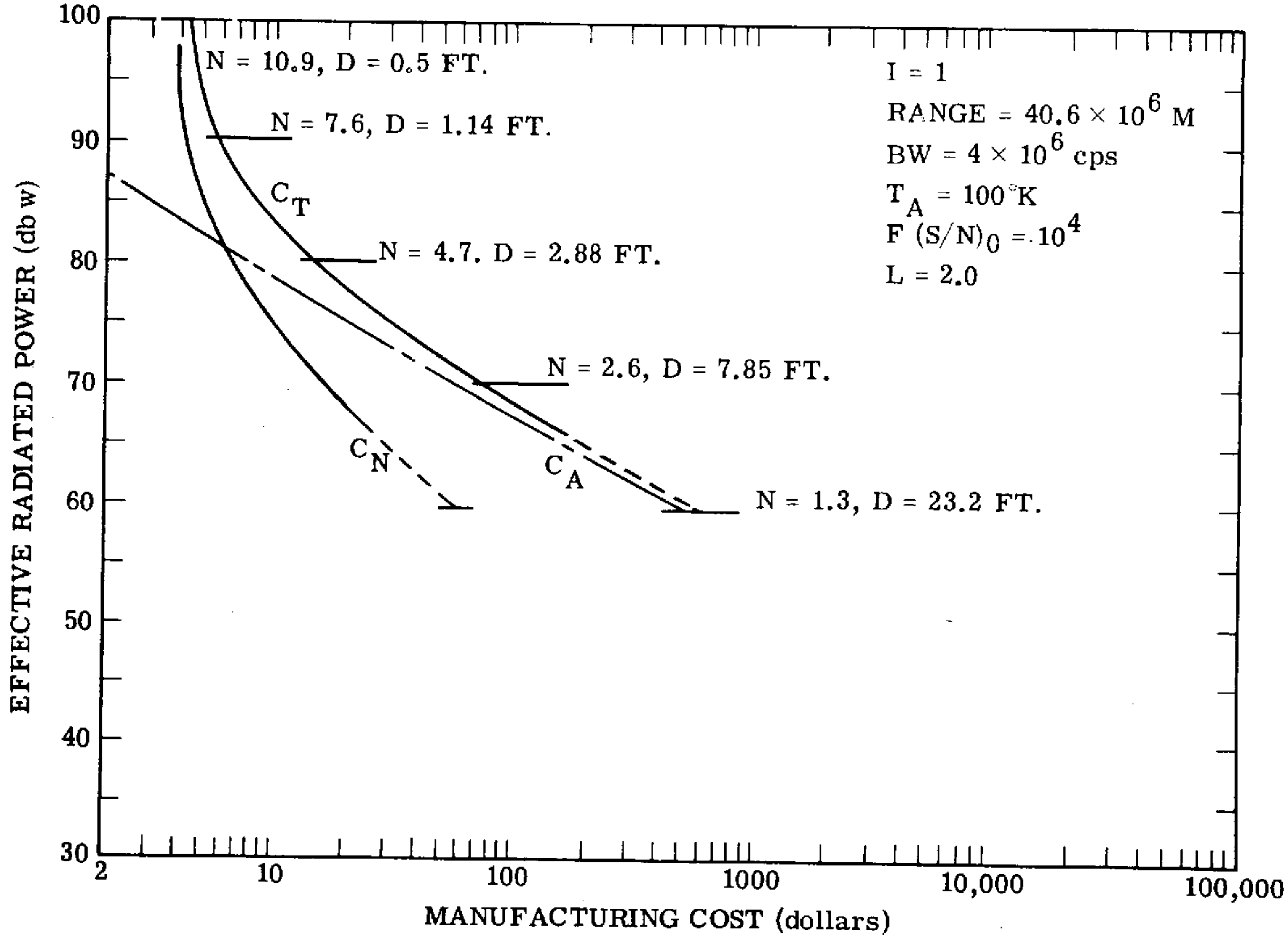


Figure 4. Manufacturing Cost of Antenna, and Tuner for a Satellite - TV Receiver (UHF)

RADIO CORPORATION OF AMERICA

S. Gubin and D. S. Bond

Direct-to-Home Satellite TV Broadcasting

Summary of Presentation

Copies of our report "A System for Direct Television Broadcasting Using Earth Satellite Repeaters," dated 1 July 1962, are available. The report examined various television satellite systems in parametric form. The basic data relating to radio transmission remain valid. The power supply proposals of the report are no longer valid because of reorientation in national nuclear power supply programs. Launch vehicles, however, have reached a high state of development and offer new choices.

NOTE: Mr. Laport stated during the open discussion period that the RCA remarks were directed toward the foundation of a reasonable approach to a technical experiment.

Frequencies for Direct-to-Home Satellite Television Broadcasting

Considering that:

- television channels are allocated in the 470 to 890 mc band,
- there is a growing number of UHF TV receivers in use,
- there are constant notable improvements in the performance of UHF TV receivers and reductions in their cost,
- an experimental TV broadcast service ought to be technically compatible with existing TV broadcast services if it is to provide a future service,
- radio propagation conditions from a stationary satellite to earth are virtually ideal, above 600 mc,
- the antenna adaptations required for direct reception from the satellite are simple and economical,
- all necessary elements relating to the entire radio system are available and proven,
- satellite antennas of practical performance and configurations can be provided for the upper end of the UHF TV frequency band, and,
- there appear to be fewer problems of frequency allocations within the existing UHF television frequency band,

we conclude that

- the best frequencies for satellite-to-earth transmission for compatible television broadcasting are the standard allocated channels at the upper end of the UHF television band.

Antennas for Spacecraft

A good balance between practicable satellite transmitter power and practicable satellite antenna structures for national or regional coverage occurs in the upper UHF TV channels.

Spacecraft Primary Power

RCA has designed and manufactured one of the largest solar cell power arrays orbited to date. These deliver several hundred watts of power. More recently, RCA has studied and conceived the prospective design of a multi-KW solar cell supply comparable in size to that needed for a broadcast satellite.

Spacecraft Transmitter and Program Link

In our opinion, the most promising transmitter concept for transmission of vestigial sideband video and accompanying FM sound is to use gridded tubes. The transmitter would be an amplitude-linear heterodyne repeater for composite video and sound signals. This composite signal would be generated at the earth-to-satellite station, where the technical characteristics of the signal would be formed, thus providing flexibility of transmission standards.

Ground Receiver Sensitivity

It is very likely that the prospective user of the TV satellite will require an antenna pointed to the stationary synchronous satellite. This antenna can be provided with a solid-state preamp at a small additional cost, assuming quantity production. This will not only improve the noise figure of present-day receivers, but will also go a long way toward the elimination of transmission line loss. The design of such an antenna will depend upon customer preferences, considering his signal-to-noise requirements as well as his budget.

Alternative Television Transmission Methods

The foregoing conclusions apply only to a television system compatible with present transmission methods and standards. It is shown in the cited report that there are other practicable transmission methods if compatibility with existing home receivers is ignored.

Direct-to-Home Sound Broadcasting

We have examined the use of 100-mc FM and 26-mc AM for direct-to-home sound broadcasting, and find both to be feasible technically should these services be desired.

These are in established broadcasting bands. The 100-mc FM band in the USA is densely occupied, so it would be necessary to have cleared FM channels for wide area or national direct-to-home coverage to the growing millions of FM receivers in use.

The 26-mc international broadcast band may have some special use. This band is less crowded than the lower frequency bands, though there are fewer receivers in homes that will tune to this band. It is the most favorable of all the allocated HF international broadcast bands to propagate through the ionosphere a reasonable percentage of the time.

* * * * *

During the discussion Mr. Haviland noted that the amplification of a composite video and sound signal with a high efficiency space transmitter seems to be extremely difficult and that it would be most desirable to handle the sound and video through separate amplifier chains. Mr. Gubin stated that it is possible.

TRW SYSTEMS

R. C. Booton

Direct Broadcast Satellite Communications

Summary of Presentation

We have limited our briefing to the technical aspects of direct broadcasting of TV into home receivers and have not considered the question of frequency allocations. Spacecraft technology and booster requirements have been analyzed which could lead to a launch in two or three years provided development could be started now. Concentration has been on U.S. coverage, approximately six million square miles.

Many assumptions and tradeoffs can be made with respect to a typical receiving system. An important parameter is the equivalent area of the receiving antenna. This can be a parabolic or, at the lower frequencies, a yagi or a small array of yagis. There is a further tradeoff. At the lower frequencies the sky noise and man-made noises are higher. These factors tend to force a compromise somewhere in the upper VHF or lower UHF region.

Important questions involving the cost for improvements in home receivers, and required signal levels, are still to be resolved. We have considered several cases. One is essentially with an untouched home receiving system with noise figures from 6 to 8 db and a high-gain antenna. For the VHF region a yagi or a yagi array with a gain of 16 db is used, and for the UHF region a 6-foot parabola is considered. Many combinations of parameters may be introduced, including the use of low-noise preamplifiers and frequency modulation.

Table 1 shows 5 configurations of receiving systems. The transmitter power requirements for U.S. coverage are given in Table 2. No man-made noise is assumed in the calculations. The RF power budget for Case II is shown in Table 3.

Several classes of satellites have been analyzed. There appears to be very little difference in the size of satellites for AM broadcast, and significant reductions in size come by going to a frequency-modulated system and installing larger antennas, from 10 to 30-foot parabolas. The weight range varies from the 7000-pound class for AM, which is in the Saturn IB - Centaur class to 250 pounds for the FM case. The latter case requires improved home receivers and larger antennas. The power supply requirements range from 22 kilowatts down to 100-150 watts.

TABLE 1. RECEIVING SYSTEM REQUIREMENTS

Case	Receiver	Antenna
I	Average quality commercial receiver; 7-14 db noise figure	Average quality commercial yagi
II	Best quality commercial receiver; 5-10 db noise figure	High-gain antenna (yagi or 6-foot parabola)
III	Commercial receiver with low-noise preamplifier; 3-6 db noise figure	High-gain antenna (yagi or 6-foot parabola)
IV	FM demodulator with low-noise preamplifier and commercial receiver	High-gain antenna (yagi or 6-foot parabola)
V	4-gc FM receiver	40-foot parabola

TABLE 2. TRANSMITTER REQUIREMENTS FOR U.S. COVERAGE

Case	Peak Power for 36-db Picture SNR (Weighted					
	57 mc/Ch.2 140' Antenna	213 mc/Ch.13 37' Antenna	473 mc/Ch.14 17' Antenna	887 mc/Ch.83 9' Antenna	3.2 Gc 2.5' Antenna	4.0 Gc 2' Antenna
I	130 kw	240 kw	2600 kw	11,000 kw	-	-
II	28 kw	32 kw	330 kw	350 kw	-	-
III	27 kw	20 kw	87 kw	130 kw	-	-
IV	130 kw	98 w	420 w	620 w	590 w	-
V	-	-	-	-	-	3.9 w

TABLE 3. RF POWER BUDGET FOR CASE II 36-db PICTURE SNR

Carrier frequency:	213 mc
Transmitter power, vestigial-sideband AM:	32 kw, peak 8 kw, average
Transmitter antenna gain (37-foot parabola):	22.4 db
Diplexer and cable loss:	1 db
Range:	22,500 n.m.
Path loss:	171.4 db
Polarization and ellipticity loss:	3 db
Receiver antenna gain (16-foot yagi):	16.1 db
Receiver signal power:	-62.4 dbm
System noise temperature:	1760°K
Received noise power, 6-mc bandwidth:	-98.4 dbm
Predetection SNR (peak signal/RMS noise):	36 db
Post detection weighted picture SNR:	36 db

The particular satellite which we have looked at in more detail would weigh in the vicinity of 6000 pounds*. The system design features are given in Table 4. An additional weight of 7000 pounds would be for an injection stage built into the satellite. The multikilowatt power supply may be an expanding solar array which could provide 8-10 watts per square foot.

Within the capabilities of anticipated launch vehicles, engines, and power techniques, and with moderate improvements in home receiving systems, a direct-broadcast TV system could be developed.

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* This weight does not include storage batteries for the 72-minute eclipse period.

TABLE 4. DIRECT BROADCAST (AM)

System Design Features

- Upper VHF - 213 mc
- 36-db weighted S/N picture
- Unmodified home receiver
- 16-foot home yagi
- U.S. coverage - 50-foot dish
- 22 kw solar array
- 8 kw (average) RF - Tetrode
- 6,000 pound spacecraft
- Integral injection stage
- Active attitude control
- Active thermal control

THE CENTRAL RADIO PROPAGATION LATORATORY*

J. W. Herbstreit

Propagation Factors

Summary of Presentation

I want to review very briefly the propagation factors involved in broadcasting from satellites. The free space loss is known as is the absorption loss, particularly the ionospheric absorption. There are some unknown factors in the absorption that might be expected from precipitation. These unknowns stem primarily from lack of rainfall statistics in different locations, but such statistics are being determined.

Most of the factors concerning polarization loss are known. If a linearly or circularly polarized signal is transmitted from a satellite, the ionosphere divides the energy into two components, one "right handed" and the other "left handed," circularly polarized when they reach the earth. When the signals from the first sputniks, transmitted on 20 mc, were received on a linear antenna, regular-type fading occurred with the signal level varying from essentially zero to its maximum.

With a synchronous satellite and frequencies on the order of 15 mc, the fades might be just a few per minute or even a few per hour, depending on the stability of the ionosphere. With a moving satellite, deep fades will occur at a rate of a few a second. An analysis of ionosphere effects, including absorption, doppler, fading, et cetera, is contained in the Proceedings of the IEEE, January 1964, entitled, "A Survey of Ionospheric Effects Upon Earth-Space Radio Propagation," by R. S. Lawrence, C. G. Little, and H. J. Chivers.

Of interest is the maximum usable frequency for vertical incidence. The ionosphere is reciprocal, as demonstrated by the Topside Sounder Program. Maps of the vertical critical frequencies for the world, will be published shortly in the CCIR and are applicable to broadcasting at HF directly from satellites.

There are two propagation factors in connection with frequency sharing. Precipitation at 4000 megacycles, for example, not only introduces absorption but also provides a source of interference which must be taken into account in developing sharing criteria. The other factor is the effects of the directivity of antennas. This is concerned with the amount of radiation that might be received off the back side of large antennas.

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* CRPL is now called the Institute for Telecommunication Sciences and Aeronomy of ESSA (Environmental Science Services Administration) which is a combination of the Coast and Geodetic Survey, the U.S. Weather Bureau, and CRPL.

Another important area of concern is that of man-made noise. A new study is being conducted by the Joint Technical Advisory Committee (JTAC) of the IEEE. This is also being done in connection with some of the land mobile work of the FCC. It is hoped to determine if the man-made noise is increasing as a function of population increase, power consumption, or other factors.

* * * * *

A discussion followed, concerning the significance of Faraday rotation versus frequency, and the optimum method of combining the two components of the signal on the ground. Conclusions were not reached and further analysis of the question is required. Mr. Allen raised the question as to whether the home receivers would require polarization diversity and power addition, and if so the costing information presented in the colloquium had not taken this into account.

STANFORD RESEARCH INSTITUTE

W. R. Vincent

Mr. Vincent pointed out that with respect to the transmission media there are only three fundamental factors - signal-to-noise, frequency dispersion, and time dispersion. In some cases for broadcast - 26 mc for example - time dispersion and frequency dispersion would be limiting factors in the quality of the received signal, and signal-to-noise might not necessarily be the factor which would rule out a usable signal. In the 1000-mc region, frequency and time dispersions become less important.

Polarization rotation is a combination of the above factors, but probably most affects signal-to-noise ratio. Man-made noise levels are so erratic in inhabited areas, that they must be defined by measurement much more accurately than in the past.

ASSOCIATE DIRECTOR OF TELECOMMUNICATIONS MANAGEMENT

EXECUTIVE OFFICE OF THE PRESIDENT

Fred W. Morris, Jr.

Mr. Jaffe and Mr. Kelleher,

I bring you congratulations and an expression of appreciation from James D. O'Connell, Director of Telecommunications Management and Special Assistant to the President for Telecommunications, for your sponsoring this colloquium. The discussions this morning and this afternoon have disclosed the fine homework U.S. industry and research institutions are doing in the field of satellite communications with emphasis on broadcast aspects.

I want to reiterate the thrust of the intent of both President Johnson and President Kennedy, and The Congress to the effect that the U.S. Government encourages the applications of space technology and its use to the benefit of all peoples of the world. Certainly, this colloquium addresses technology related to this subject. This is not to say that we can, at this time, unilaterally encourage development of broadcast satellites without consideration of policy and international agreement questions.

To better inform you concerning our office, let me define several of our interests and responsibilities:

1. The President's desire to apply space technology to improve global communications, including his program and task considering "Education for the World";

2. National Telecommunications Policy;

3. Advice to the Department of State concerning negotiations in the international political arena, as well as negotiation of international radio regulations;

4. Carrying out of the President's responsibilities under the Communications Satellite Act of 1962 (including work with the Federal Communications Commission, government agencies, and the Communications Satellite Corporation);

5. Radio spectrum utilization; and

6. Frequency allocation for U.S. Government use.

To better inform you concerning the functional interests of Director of Telecommunications Management, we have a chart available for your information.

In our discussions in this meeting so far, there has been acknowledgement of the cautions concerning the status of current international radio regulations. I wish to reiterate these cautions and ask Bill Plummer - who is responsible to Mr. O'Connell for Frequency Management - to remark in some detail. These cautions include:

1. The prohibitions upon international broadcasting from international territory, which by inference includes space;

2. Limited frequency allocation and the long lead time for negotiation of additional allocations; and

3. Signal density limitations in shared spectrum bands. Bill Plummer will address these concerns and cautions.

An interesting point concerning the last item - only this week have we been able to clear the way permitting construction to proceed for the Communication Satellite Corporation's earth station in Hawaii. A major problem of consideration has been the potential interference to an earth station which might be located anywhere in the State of Hawaii, due to present and planned microwave and radar facilities. While we believe the subject has been cleared up satisfactorily, it has been a major point of conjecture.

Acknowledging our concern at the national level that spectrum limitations must be defined and the needs of the Space Services be determined, the Director of Telecommunications Management is in the process of requesting proposals for a contractual "Study of the Needs of the Space Services Between Now and 1980, and the Means of Satisfaction in the Light of Spectrum Saturation." A Request for Proposal is currently being released; it is unclassified, and invites proposals from organizations not involved in system design and development. A prospective bidders' conference is planned and will be announced in the RFP and Commerce Daily to be convened in our offices. While we will not be able to fund studies with system design and development organizations, we will be pleased to receive results of independent studies considering the subject.

Perhaps you are interested in some aspects of the study we propose to have conducted. The basic objective is to determine spectrum space requirements for allocation to the Space Services during the period extending to 1980. The study is to be predicated upon the use by the Space Services of the most practicable techniques to conserve spectrum space and to provide adequate facilities for government and non-government space and satellite communications (including - but not limited to - communications with ships, space vehicles, and aircraft, as well as network and direct broadcasting to the general public), navigation, meteorology, and space research. The objective of the study is to define the problems in sufficient depth to clearly detail the scope of the overall problem and to identify the decisions required. The questions to be answered in connection with the various Space Service requirements include:

1. Can we operate within the existing framework under:

a. The technical limitations of current national and international regulations; and

b. Shared and exclusive allocations?

2. If not, what steps are necessary to make such services possible?

We wish studies in depth in areas including:

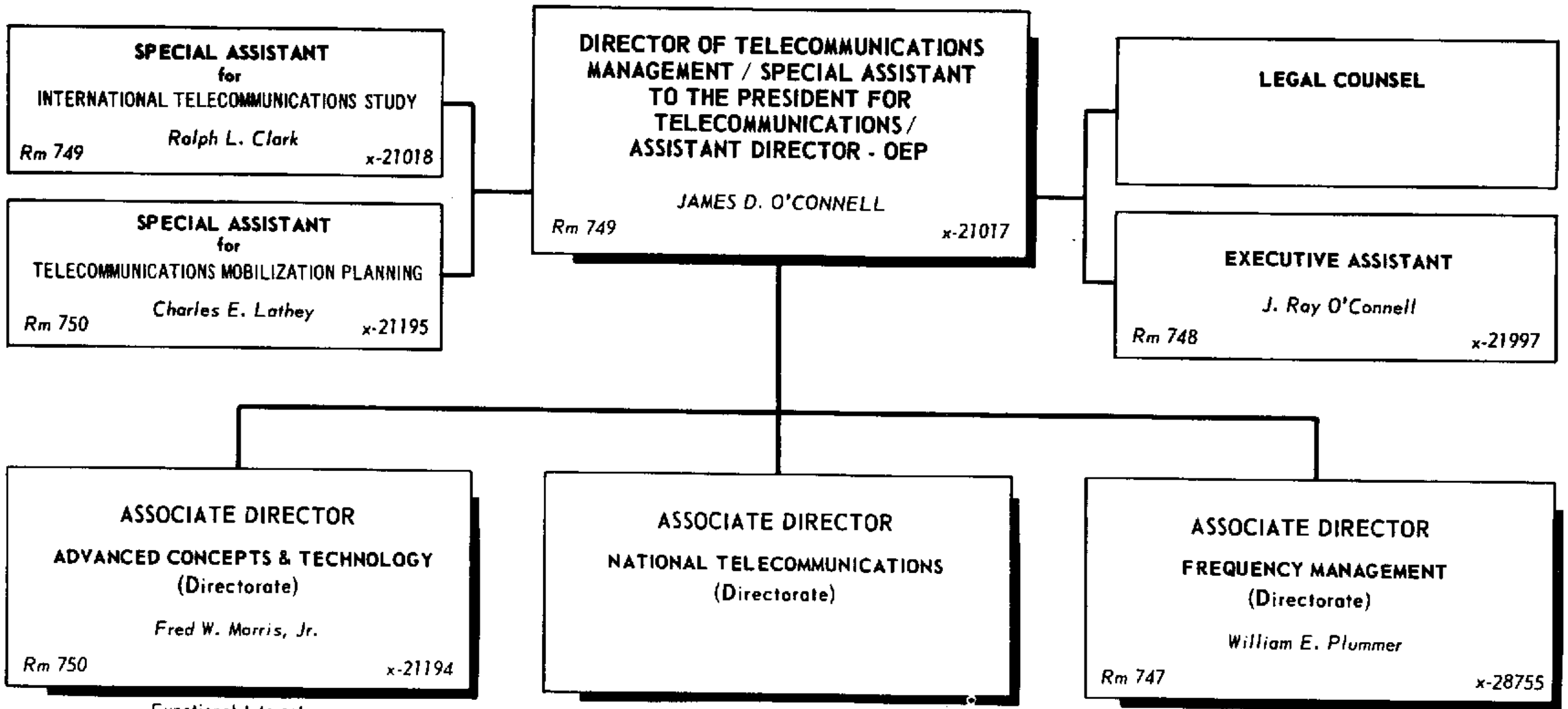
1. Interference between military satellites, manned orbiting spacecraft and commercial communications satellites;

2. Frequency implications of current proposals for use of the Space Services;

3. An inventory of the progress in technology which would view and make possible improvements in the Space Services projected; and

4. Projections of increase in communications demand and the growth in communications satellite systems on a global basis.

In the light of the above, we wish to identify spectrum saturation problems and receive recommendations concerning the spectrum space requirements for allocation to each of the identified applications of space technology during the period extending to 1980. The recommendations should stipulate whether the spectrum space should be on a shared or exclusive basis, together with any limitations affecting the order of frequency required.



Functional Interests:

- SATELLITE COMMUNICATIONS
- INTERNATIONAL TELECOMMUNICATIONS
- TELECOMMUNICATIONS TECHNOLOGY
- TELECOMMUNICATIONS ECONOMICS
- ADVANCED CONCEPTS

Functional Interests:

- NATIONAL COMMUNICATIONS SYSTEM
- PRESIDENTIAL COMMUNICATIONS
- DOMESTIC CARRIER
- TELECOMMUNICATIONS MOBILIZATION
- WARTIME CONTROL OF TELECOMMUNICATIONS

Functional Interests:

- FREQUENCY SPECTRUM UTILIZATION
- GOVERNMENT FREQUENCY ASSIGNMENT
- EMBASSY RADIO STATION AUTHORIZATION

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Interdepartmental Governmental Code 128 plus extension number.

(AS of October 1, 1965)

OFFICE OF THE DIRECTOR OF TELECOMMUNICATIONS MANAGEMENT
EXECUTIVE OFFICE OF THE PRESIDENT
WASHINGTON, D.C. 20504

FEDERAL COMMUNICATIONS COMMISSION

E. W. Allen, Chief Engineer

Much of the technical area that we in the Commission have knowledge of and have been concerned with has already been examined here today. Most of the work that the staff of the FCC has done in the specific fields of broadcasting from satellites and in the relaying of programs - broadcast programs - has been in connection with CCIR. We have done some work in the area of communication satellites, both within CCIR and within the Commission, on applications for communication satellite systems.

We would certainly endorse the opinions here that a lot of the fundamental work has been done by CCIR. We know that it is more or less provisional, that the work is continuing, and I would hope that, in addition to those who have already contributed to CCIR, some of the others who may not have been as active in the past would get into this work so that we can all be talking the same language and be working from a common base. I think it is a very good start in all three of these areas - the COMSAT area, broadcasting area, and the program transmission areas.

A part of my talk here today, I thought I was going to be ruled out by Leonard Jaffe's remarks this morning about not bringing in controversial and policy problems, but I understand that it is in order to point out some of the problems. I think Mr. Morris has already pointed out some of these.

While we recognize that this colloquium is called upon to examine technical matters relating to broadcasting and broadcast program distribution, I would like to stress that there are many non-technical policy and public interest questions, which will have to be considered carefully and resolved by the agencies which have the legal responsibilities in these areas before we will be able to move forward to provide some of these services.

Indeed, it is quite possible that some of these policy questions will prove to be more difficult of resolution than some of the technical questions.

Some of these problems which come immediately to mind are particularly in the area of domestic broadcasting from satellites and the program distribution area; first, whether it is in the public interest to provide for nationwide broadcasting of a single program under private control; second, whether enough channels can be made available to provide for diversity of control. Since our broadcasting is not a public utility but a privately operating type of service, the only control is competition, the only real control. You have competition in diversity of control. These are real problems as many of you who are familiar with the Commission's processes are aware.

Third, what effect would such broadcasting have on our present system with its provision for local program control and origination?

Fourth, whether program distribution should be provided by private systems such as the existing ABC Broadcasting Company proposal for program distribution, or whether they should be provided by common carrier.

Fifth, if by private systems, what effect would the draining of the revenue from the principal television networks have on the provision of other television relay links by common carriers and on the general common carrier service, i.e., the viability and the impact on the present common carrier services.

If it is the consensus here that broadcasting and broadcast program distribution from satellites are now or soon will be technically feasible, it would seem to be just good common sense to set in motion the procedures for resolving the several policy problems before an extensive program of research and development is undertaken to resolve residual technical questions.

I would like to give a few examples to highlight this point.

There are many technically feasible systems which many people feel are desirable and on which much money has been spent, which have not been able to be provided for at the present time.

An example of this is facsimile. There have been many proponents of the facsimile broadcast service over the years. Facsimile was known even in the early days of telegraphy, around 1840. Broadcast facsimile has had many proponents. So far we have not provided a regularized service; it wasn't viable.

Stratovision - the broadcasting of television from flying airplanes - so far this has not been provided. We are still in the works in certain respects.

Super power, clear channel in the AM band - it is perfectly feasible to have stations of 750 kilowatts. It raises problems of concentration of control, overlapping services, and things of that nature.

A broad-band, multiple-access land mobile system. These have been proposed for many years and certainly they would be supported adequately by the public if such a system could be provided. So far we have had no space provided for this.

I think we should look very closely at some of the policy problems, and at least have a foreseeable or a nominal resolution of these factors before we go all the way to solving the technical questions.

Both direct broadcasting and program distribution by satellites raise questions with respect to frequency allocations, as have been recognized here. While this is a matter of great concern to this colloquium, it also involves matters of policy and the consideration of public interest factors.

Should the necessary channels be set aside in bands presently allocated to broadcasting, or should new bands be provided? From the technical standpoint it appears that the present FM broadcast band is very suitable for FM broadcasting from satellites, and that the widespread public ownership of receiving equipment should make the service attractive from the outset.

A new band, if one could be found, would have the same deterring effect on the new service as has been faced by FM and UHF TV systems in the past. The future provision of appropriate channels from presently allocated frequency bands, or the setting aside of separate frequencies in these frequency ranges for FM and TV broadcasting from satellites, would cause serious disruption to present terrestrial allocations and assignment patterns, and public interest questions are unquestionably involved in such decisions.

As I have said, ABC has filed an application for a system of program distribution from satellites. On the basis of our past study of this problem, there is some doubt that this can operate in the bands presently allocated for communication satellites - those bands which are shared with terrestrial microwave systems and for which appropriate sharing criteria have been developed by CCIR. They have also been adopted by ITU and EARC regulations.

The principal problem here, as we see it, is the provision of isolated receiving sites for the program distribution system when near the terrestrial broadcast transmitters. Your conclusion depends, of course, on the kind of system that you envisage. If you envisage one receiving site for each broadcast site, you have one problem. If you envisage one receiving site for a community or an occupied, populated area, you may have another system.

But enough sites comparable in isolation to the sites required for communication satellite earth stations may not be available, and the program distribution system may need to work with stronger signals which cannot meet the limits imposed on the shared bands. If this is true, no frequency bands are now allocated for such a system either nationally or internationally, and this would appear to be necessary before such systems can become operative.

These thoughts are primary and will be either confirmed or revised in connection with a further study of the ABC proposal. This matter is still under consideration, and whether or not it will get in the door is not fully answered at this time.

With respect to these policy questions, the Commission and its staff stand ready to discuss these matters with the interested agencies and to take such steps as are necessary to resolve such problems which lie within the Commission's area of interest. The filing of an ABC application for the provision of television network service by satellite should furnish a vehicle for considering some of these problems.

UNITED STATES INFORMATION AGENCY

VOICE OF AMERICA

George Jacobs

I believe, at least as far as the audience present in this room and as far as what has already been discussed today, that I represent the only organization that is a potential user of a broadcast satellite.

As a potential user, the U.S. Information Agency has strong, but mixed concern about a broadcast satellite. On the one hand we recognize the great potential that such a satellite might offer in carrying out the Agency's prime mission of telling America's story overseas. For this reason, since the very beginning of the space communication era, USIA has played a key role in urging the development of a national policy concerning broadcast satellites. At every opportunity we have stressed the need to determine the feasibility of a communication satellite with the capability of relaying radio and TV broadcasts directly to the homes of listeners and viewers throughout the world. Along these lines, we have been a major contributor to the studies being carried out by the International Telecommunications Union and at international conferences dealing with broadcast satellites.

On the other hand, the Agency's long years of experience in the field of international broadcasting leads us to believe that a broadcast satellite, aside from being technically feasible, must fulfill certain other basic requirements if it is to be a success. I believe I can narrow these requirements down to two, and state them rather simply. First, broadcast satellites, to be really useful as far as we are concerned, should provide a means by which we can increase our audience throughout the world, deliver a stronger radio signal than we can do at present with our ground-based transmitters, and reach more people than we do now. Second, we should be able to do this with broadcast satellites at a comparable cost, or cheaper, than we can now do it with ground-based transmitters. If it does not fulfill at least one of these requirements, no matter how technically feasible a broadcast satellite might be we would be pessimistic about its usefulness from a practical point of view.

To establish some sort of reference level, I would like to take a few minutes to tell you what we are doing now in the way of signal coverage from our ground-based transmitters, and what it costs us to do this. I'll leave it up to the experts assembled in this room to eventually determine how broadcast satellites will compare in signal and cost to what is now being done.

Let us take, as an example, the new Voice of America plant at Greenville, North Carolina. This plant consists of 18 high power short wave transmitters ranging in power between 50 and 500 kilowatts. The plant transmits a total of 260 hours a day to Western Europe, areas of Africa, and the entire Western Hemisphere from the Texas border to Cape Horn, off the southern coast of Chile. At times, programs in as many as six different languages are transmitted simultaneously from Greenville. The gross cost of operating this plant amounts to approximately $3,000,000 a year. This includes all operating costs, salaries, overhead and depreciation and amortization of equipment.

Focusing on just the Western Hemisphere, transmissions start at 6 AM and end at midnight, local time. At times four different languages are broadcast simultaneously to this area. Over this entire area VOA's signals exceed 1/2 millivolt per meter during the daytime and 2 millivolts per meter during the evening hours. About 70 of the total of 260 hours transmitted daily from Greenville are beamed to the Western Hemisphere. This means the prorated cost to USIA for reaching the entire Western Hemisphere south of the USA amounts to less than $1,000,000 a year.

Now let's look at the African Continent. The VOA has a new shortwave plant near Monrovia, Liberia, where eight high-power shortwave transmitters, ranging in power between 50 to 250 kilowatts, reach at least 90 percent of the African continent, with daytime signals in excess of 1/2 millivolt per meter and nighttime signals in excess of 2 millivolts per meter. This costs USIA approximately $2,000,000 a year.

I believe that these signal strengths and costs are good yardsticks to go by. What will the annual costs be, including launch and amortization for broadcast satellites to achieve the same sort of coverage? Or conversely, for the same cost as for present ground-based transmitters, what signal levels and coverage zones would be possible with broadcast satellites? Unless a broadcasting satellite can provide a signal competitive to what is being provided at the present time by ground-based transmitters, will anyone be attracted to it? Someone mentioned earlier today a broadcast satellite that would deliver a signal of 10 microvolts per meter. From the competitive standpoint, how will this compare to a 1/2 or 2 millivolt per meter signal for drawing an audience? Not very well, I fear.

On the television side it may be somewhat different. There is no way at present for USIA or anyone else to deliver a television signal directly to a listener over great distances. The Agency has a very active television service, and we make use of jet-transported local-placement of USIA television programs over hundreds of stations throughout the world. When we can afford it, we can also use the Early Bird satellite to relay live broadcasts to cooperating networks in Europe for rebroadcast locally. But we cannot reach a listener directly. Here is where a broadcast satellite may have its greatest usefulness in the future.

Of course, the problem of designing a satellite for television broadcasts becomes many times more difficult than for radio because of the higher power levels required, and the different technical standards used in various areas of the world.

My only contribution to this seminar is to reflect the views of a potential user of a broadcast satellite. My Agency again strongly urges the development of an experimental broadcast satellite program as soon as possible so that we may be able to get some of the answers that we are seeking from direct experimentation rather than from opinions. I do, however, want to leave the thought that in the long run, to be really useful, a broadcast satellite must be able to do a better job, more cheaply, than can be done by present ground-based techniques - and the present techniques are pretty good.

* * * * *

The following points were brought out during the questioning period.

1. On the average, present receivers require an investment of between $15 and $50 for a listener to hear the Voice of America. Receivers to tune in signals from a broadcast satellite should be in the same price range in order to be competitive.

2. The total annual cost of the Greenville plant (18 high-power transmitters) is roughly $3,000,000 per year. This included a $1,600,000 figure for annual depreciation and amortization of the plant's facilities (based on a 15-year life). Since only 70 of the total of 260 daily hours of broadcasts transmitted from this plant are beamed to the Western Hemisphere, south of the USA, the gross annual cost for this service is less than $1,000,000.

3. The USIA's annual budget runs about $140 million. Of this amount, the VOA gets about $26 million, of which approximately $14 million is allotted to engineering functions. The VOA's world-wide network of approximately 100 transmitters, on the air for a total of nearly 1,000 transmitter hours daily, is funded from this amount. The total investment in equipment (transmitters, antennas, land, etc.) to accomplish this global coverage is approximately $200 million.

THE RAND CORPORATION

Cullen Crain

Since about 1960 it has been clear that some technical capability exists for broadcasting-- in some sense of the word-- from space vehicles. Since AM and FM voice broadcasts require the most modest capabilities, such broadcasts were technically achievable first. As we continue our space development efforts-- as boosters get more powerful, as satellite raw power systems improve, as our abilities to deploy high gain antennas with precise and controllable orientation develop, etc.--this capability will continue to grow significantly. There is little question, for example, about the technical feasibility of being able to develop a TV broadcast capability from space vehicles to home-type receivers, if additional and reasonably modest antennas are added to the home terminal. It is, or should be, clear that ultimate exploitation of this growing technical capability for space broadcasting must involve proper considerations and evaluation of many other questions, such as economics and those Mr. Ed Allen and others have referred to previously.

From the discussions today it is clear that there is a wide spectrum of potential broadcast possibilities with an accompanying wide spectrum of satellite characteristics. There would appear to be three categories into which space broadcasting considerations--such as technical, policy, national, and international regulations and implications, cost, etc.--could be properly divided. These are:

1. Prestige programs of the United States Government. A timely question to explore in depth is: "What applications of our current and near future technology could be used for these purposes?"

2. Broadcasting to serve a particular United States Government purpose, such as information distribution to other countries, educational TV, or related things.

3. Purely commercial development and applications. The various considerations of the foregoing categories will involve considerably different policy and regulation questions, economic factors, and so forth. Such items need to be resolved much further before it would appear to me attractive to invest appreciable effort in detailed work on any particular concept.

Some of the technology alluded to previously, which will provide increasing potential capabilities for satellite broadcasting, will evolve naturally from the various space programs;

however, there are certain areas in which the necessary technology will not likely evolve unless we determine particular missions for broadcasting from satellites and decide to proceed. Therefore, we do have a problem of isolating and pushing ahead in those areas which will not be adequately nourished and developed unless we give direct attention to the possible useful and important roles of broadcasting from satellites.

OPEN DISCUSSION

Chairman: J. J. Kelleher

1. Mr. Kelleher stated that NASA is now in the technical feasibility assessment phase with respect to broadcast satellites preparatory to the consideration of an experiment.

2. Mr. Andrus noted that the question of the signal levels required for quality reception has not, as yet, been resolved. He referred to the initial action of the 1959 EARC conference.

Mr. Allen advised the meeting that the question is still being studied and that CCIR Report 215, which was restudied at the Monte Carlo meeting, contains suggested signal levels. Mr. Jacobs added that Report 215 applies CCIR signal levels and that the question of satisfactory levels, terrestrial as well as space, is a continuing study of the CCIR.

3. Mr. Herbstreit inquired if any consideration had been given to the French proposal for broadcasting from a passive satellite, using corner reflectors. The discussion which followed brought out the following points:

- The system would require 100-200 foot antennas (Haviland)
- Dispersion reflectors would require development (Haviland)
- The technical feasibility of active satellites is more current than the French proposal (Crain)

4. Mr. Crain reiterated his earlier statement with respect to the need to study the non-technical policy questions in parallel with the technical considerations in order to be confident that an experiment will lead to the resolution of important system application criteria, i.e., policy questions versus experimental approach.

Mr. Laport cautioned against attempting to idealize with respect to a new class of service. As examples, aircraft interference on TV and high-frequency fading and interference have not prevented the service. If a service, although imperfect, can be provided, it has a potential use provided it meets economic criteria. Therefore "in the early stages of considering a technological venture for exploration, we don't have to consider whether it is 'go' or 'no go' depending on its perfection."

However, it was noted (by an unidentified voice) that any experimental program must be directed to a specific approach.

5. Mr. Gould suggested some important decisions which should come out of the meeting. Of primary importance is the definition of the classes of service which might be engaged in and recommendations to the appropriate agency for frequency allocations. In addition, he stated that some urgency applies in the designation and reservation of the frequency and bands required because of the continuing demands on the spectrum and the congestion interference which will result.

It was pointed out by Mr. Andrus that since both the UHF band and the microwave regions above 1 Gc were talked about in the presentations, it might not be clear to the group which of these is better from a technological point of view. He suggested that, on purely technical grounds, a distribution and educational broadcast system could be satisfied by either UHF or microwave bands; however, the questions raised by Mr. Allen would have an important bearing on this subject.

Mr. Vincent suggested that, when the type of broadcasting service to be performed has been defined, the appropriate section of the spectrum could be rapidly determined.

6. Mr. Taylor (verbatim) - It seems to me that it is very important that before we can possibly determine what are optimum frequencies, we have to be very clear on what service we are looking at, whether it is for broadcasting audio, whether it is for broadcasting television, whether it is for community type of service. One can divide each of those classes of service into two quite distinct areas. We may get one answer if we are looking at a national type of coverage, and possibly quite another answer if we are looking for an international type of coverage.

It would seem to me, therefore, that basically we have six possible permutations. Before we can go very far in examining what are the frequencies which are most appropriate to each of them, and to the technologies which are appropriate to each of them, we have to decide are we interested in the whole lot or are we interested in one or more.

I believe sincerely that the characteristics of each are quite different.

If we take, for example, only the question of frequency for a television broadcast service, the answers may be different in different parts of the world, different whether we are considering a highly developed national area or whether we are considering a national area which is of very modest development, and so forth.

I believe we have so many problems here of different types of service that we could perhaps be well occupied in defining just what those types of service are.

7. Mr. Allen (verbatim) - I want to address myself to the proposition that it might be possible to identify frequencies which, in this case, if it is private broadcasting within the United States, it would be the FCC which would have to set forth the procedures to reserve them.

As most of you who have had any dealings with the FCC, this has to go through a regular legal procedure. For example, if we say that we would conclude that the upper UHF is best for television broadcast direct to home, for an area the size of the United States, for example, we are not talking here of setting aside some unused frequencies and reserving them for a future experiment. These frequencies are now in use. They have been allocated to living and going services. In order to take them away from those services, you have to make a showing in a rule-making proceeding that your need for them is greater than the people who are there now and set up some kind of procedure for amortizing and moving the occupants. This is not something that a few people can get together and say we will chop off this band. You have an exceedingly difficult problem in the areas where you have present occupancy.

8. The following recommendations were proposed by Mr. Haviland:

a. That study material presented at the meeting be prepared for publication in the IEEE transactions on broadcasting.

b. That further studies, particularly in propagation, be undertaken, possibly by CRPL (ITSA of ESSA).

c. That the FCC give consideration to instituting a docket of inquiry on space broadcasting in one or two years.

d. That Congress, and in particular the House Committee, have a public inquiry fairly soon.

NOTES:

1. Further in the discussion, Mr. Morris responded to recommendation d. above and stated that the DTM study "is really preparatory to possible Congressional interests, international interests certainly, and, in turn, FCC possible dockets."

2. Mr. Allen pointed out that the ABC proposal is now before the Commission for either granting or denying--or granting in part (point c. above).

MR. KELLEHER - Gentlemen, I want to express again my very sincere appreciation for your participation in the colloquium. I did not anticipate the wholehearted cooperation that we have had. We will certainly take the information which you have furnished and give very serious consideration to it.

Thank you very much.

BROADCAST SATELLITE COLLOQUIUM - NASA

October 8, 1965

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